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DESIGN, DEVELOPMENT AND FABRICATION OF TRAINING ROUND TO SIMULATE PROJECTILE, 155-MM, HE, M107 (XM804) (PHASE I)

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FINAL TECHNICAL REPORT FOR PERIOD 9 FEBRUARY 1978 - 28 FEBRUARY 1979

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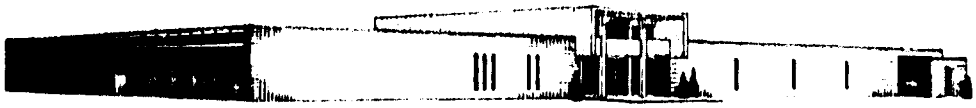

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Projectile	Testing	M409A1	C1064 Steel	Core
Training	Casting	Forging	Ballistic Similitude	Chill
HE	Inert	Heavy-Wall	Pressure-Casting	(Continue)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

On 9 February 1979 Chamberlain Manufacturing Corporation received the subject ~~contract to design and~~ to develop a 155-mm Training Projectile (XM804) which would be similar to the standard 155-mm, HE, M107 Projectile but would be significantly more economical to manufacture. The following four design approaches were investigated:

(1) A forged body with "heavy" walls, next page

(Continued)

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19. Key Words (Continued)

Reynolds Engineering
Reliable Pattern and Foundry Company
Vulcan Foundry

20. Abstract (Continued)

(2) An inert-filled (forged) M107 shell ;
(3) A pressure-cast shell , and
(4) A sand-cast shell.

The sand casting approach was eliminated early in the program based on preliminary studies which indicated that this method would not be cost-effective. A forged "heavy wall" XM804 Training Projectile design was developed which simulated the HE-loaded M107 Projectile ballistically and would withstand firing at Charge, Zone 7 as evidenced by dynamic tests. (Charge, Zone 5 is considered the maximum charge for training purposes.) Dynamic tests also showed that the inert wax load in the standard 155-mm, M107 Projectile can be replaced by the lower-cost inert Hydro-Cal load. A method for manufacturing the XM804 Projectile by pressure-casting was demonstrated successfully.

Calculations based on this investigation indicated that the cost savings for the forged and the pressure-cast "heavy wall" XM804 Projectile would be 41% and 48%, respectively, under the standard round cost.

CHAMBERLAIN MANUFACTURING CORPORATION

FINAL TECHNICAL REPORT

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The findings in this report are not to be construed as an official Department of the Army position, unless so designated by the authorized documents.

ABSTRACT

On 9 February 1979 Chamberlain Manufacturing Corporation received the subject contract to design and develop a 155-mm Training Projectile (XM804) which would be similar to the standard 155-mm, HE, M107 Projectile but would be significantly more economical to manufacture. The following four design approaches were investigated:

- A forged body with "heavy" walls
- An inert-filled (forged) M107 shell
- A pressure-cast shell
- A sand-cast shell

The sand casting approach was eliminated early in the program based on preliminary studies which indicated that this method would not be cost-effective. A forged "heavy wall" XM804 Training Projectile design was developed which simulated the HE-loaded M107 Projectile ballistically and would withstand firing at Charge, Zone 7 as evidenced by dynamic tests. (Charge, Zone 5 is considered the maximum charge for training purposes.) Dynamic tests also showed that the inert wax load in the standard 155-mm, M107 Projectiles can be replaced by the lower-cost inert Hydro-Cal load. A method for manufacturing the XM804 Projectile by pressure-casting was demonstrated successfully.

Calculations based on this investigation indicated that the cost savings for the forged and the pressure-cast "heavy wall" XM804 Projectile would be 41% and 48%, respectively, under the standard round cost.

TABLE OF CONTENTS

1. INTRODUCTION AND BACKGROUND

1.1 On 9 February 1978 Chamberlain was awarded the subject contract to design and develop a 155-mm Training Projectile, XM804, which would be 40% to 50% more economical to manufacture than the 155-mm, M107 HE Projectile and still meet the following requirements:

- Have the same exterior configuration as the M107 Projectile.
- Match the M107 Projectile ballistically.
- Withstand the Charge, Zone 5 gun firing environment.

1.2 An estimated quantity of more than 200,000 each inert M107 Projectiles per year is needed to train and maintain the proficiency of field artillery crews. The expense of using the standard HE M107 round for this purpose might restrict adequate training. The development of an inexpensive inert facsimile of the M107 round which had ballistic similitude would assure the maintenance of fully trained artillery crews.

1.3 This initial phase of the program included estimates of initial casting facility costs and rationale plus full scale forged and cast unit production cost and rationale based on quantities of 200,000 units per year for five years.

2. CONCLUSIONS

2.1 The objectives of the subject contract were met or exceeded by the accomplishment of the following work:

- A design was developed for the forged 155-mm, XM804 "Heavy-Wall," Empty, Projectile. NOTE: The "heavy wall" design simulates the HE loaded projectile by utilizing a heavier steel wall to replace the HE.

- Because post-heat treatment is not required to obtain the required physicals, the XM804 heavy-wall projectile can be fabricated from AISI C1340 steel at lower cost than from the originally specified AISI C1046 steel.

- Dynamic firing of 155-mm, XM804 Projectiles and standard 155-mm, M107 Projectiles showed that the XM804 round had the required ballistic similitude.

- Metal Parts Security Tests showed that the XM804 Projectile would withstand the environment imposed by firing at Charge, Zone 7. (Charge, Zone 5 would be the normal maximum charge for training purposes.)

- Production cost estimates showed that the forged training round represents a 41% savings in manufacturing costs.

- The results of dynamic firings indicated that the inert "Hydro-Cal" load may be a substitute for the inert wax load in the standard 155-mm, M107 Projectile.

- A method for manufacturing the XM804 Projectile by pressure-casting was demonstrated successfully. Further development is necessary to improve the quality of the castings.

3. RECOMMENDATIONS

3.1 The following recommendations were based on the results of work accomplished during the performance of the subject contract.

- It is recommended that the forged 155-mm, XM804 "heavy-wall" projectile be type classified and placed in the inventory as soon as possible.

- It is recommended that additional work be performed to improve the pressure casting method of manufacturing the XM804 Projectiles.

- It is recommended that the three cast XM804's now at Yuma Proving Ground be gun fired as soon as possible to verify their structural integrity.

- Dynamic firings at Charge, Zone 7 should be conducted on the "Hydro-Cal" loaded M107 Projectile to prove the suitability of this load.

4. DESIGN APPROACHES

4.1 The program was initiated with cost studies for the purpose of selecting one forged projectile concept and one cast projectile concept which were to be developed upon Government approval. The following types of body designs were investigated:

- A forged body with "heavy" walls
- An inert-filled M107 shell (forged type)
- A pressure-cast shell
- A sand-cast shell.

Of these four approaches, the sand casting approach was eliminated early in the program based on preliminary studies which indicated that it would not be cost effective. The estimated cost of the rough casting, itself, was considerably higher than the estimated cost of the forging. The sand cast version of the projectile could be completed only as a two-piece assembly which would have generated additional costs and potential production problems.

4.2 The standard M107 Projectiles currently are made from AISI C1046 heat treated steel; however, AISI C1064 heat treated steel is specified as an alternate material and is available at lower cost. Therefore, the cheaper alternate 1064 steel was considered in the XM804 cost estimates. Because a porosity seal was not required for inert rounds, the Base Cover (Ordnance Drawing No. 10535928) was omitted from the XM804 and inspection of the inside cavity for pits and subsequent reclaim operations were eliminated. In addition, the loading nose plug (lifting eye) was omitted and the nose threads were to be protected by a thin plastic plug cover.

4.3 The following design parameters were established for both the cast and the forged XM804 Projectile:

- Weight: 94.7 lbs. ± 1.3 lbs. (Weight Zones 4 and 5)
- Center of Gravity: 9.36 inches from base
- Moments of Inertia: Polar - 499.2 lbs.-in.^{2}
  Transverse - 4,311 lbs.-in.^{2}

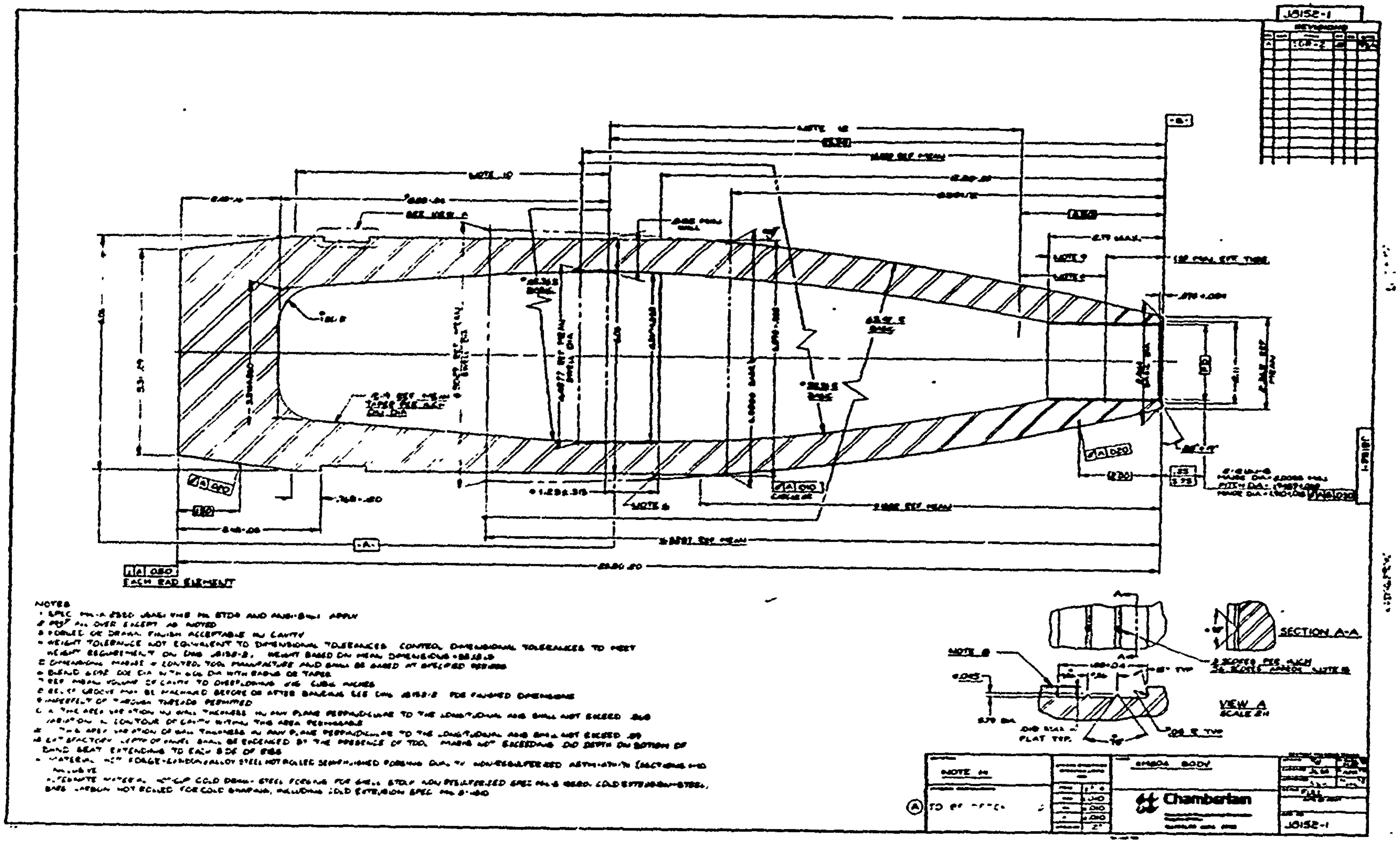
The nose fuze was included in all of the above calculations.

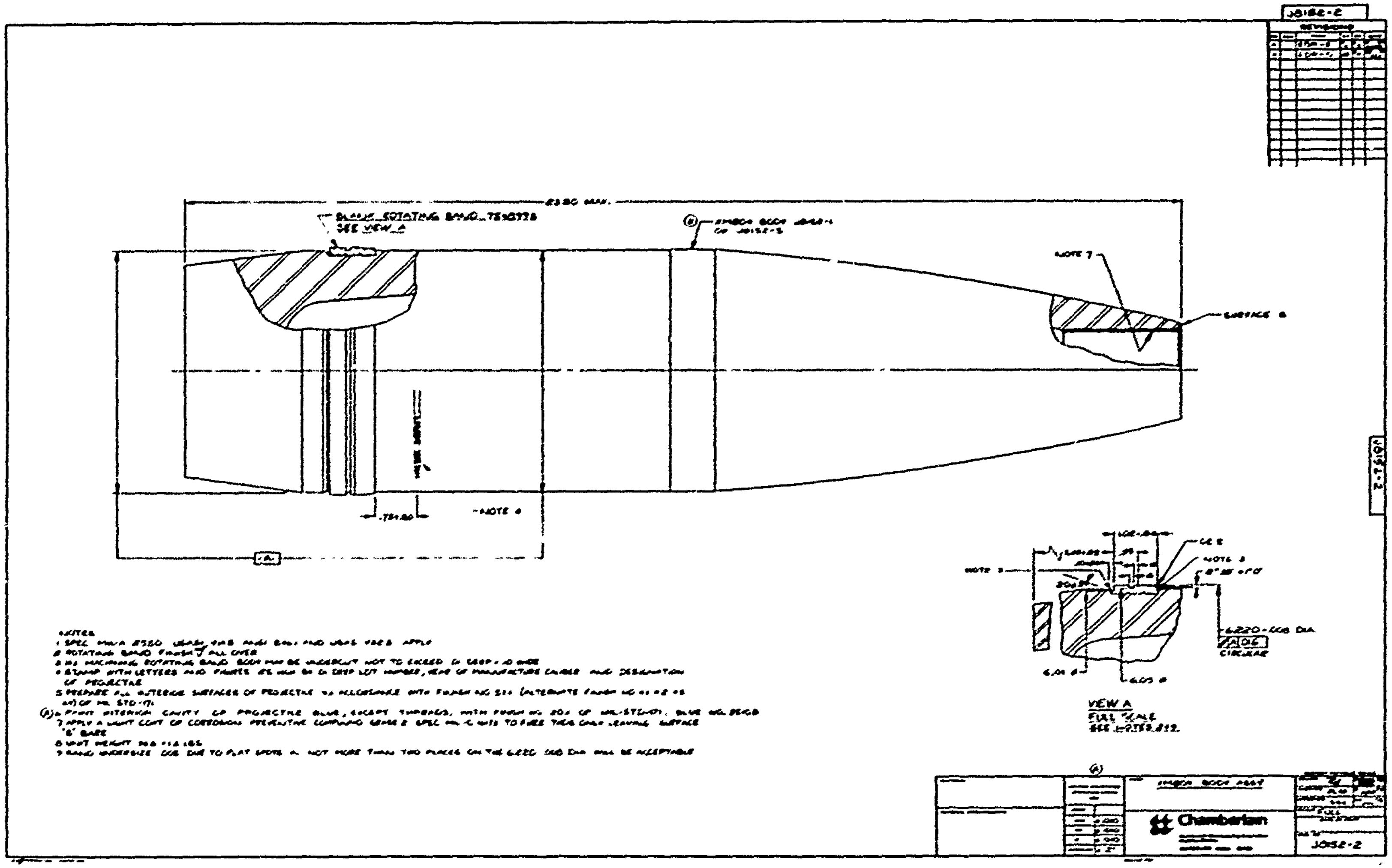
Drawing No. J8152-1 on the following page shows a "heavy-wall," 155-mm XM804 Projectile Body design which was completed during this program. Also completed were the associated body assembly design and the projectile marking diagram which are shown by Drawing Nos. J8152-2 and -3, respectively, on Pages 7 and 8. An exterior ballistics study was performed on the heavy-wall, 155-mm, XM804 Projectile design described above and the standard 155-mm, M107 Projectile. This study was based on the "Engineering Handbook for Control of Projectile Flight Characteristics" (AMCP Pamphlet No. 706-242). Tabulated below are the data from this study:

	M107 DATA PER ARRADCOM	BALLISTIC ESTIMATES (THEORETICAL DATA)	
		*M107	**XM804
Weight (Lbs.)	95.00	95.03	94.91
Center of Gravity (Inches from Base)	9.36	9.41	9.38
Polar Moment (Lbs.-In.^{2})	499.2	492.1	514.7
Transverse Moment (Lbs.-In.^{2})	4,311.0	4,181.6	4,309.6
$\frac{\text{Polar Moment}^2}{\text{Transverse Moment}}$ (Dimensionless)	57.81	57.91	61.47
Stability Factor (Dimensionless)	1.50	1.51	1.60

* Based on Mean Dimensions.

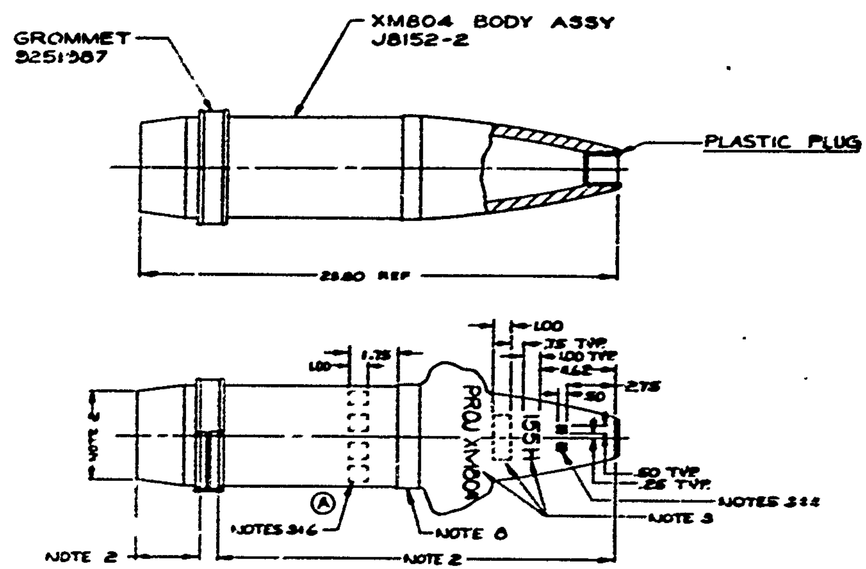
** Heavy-Wall Projectile Based on Drawing No. J8152-2.


J0152-1
NOTES
SECTION A-A
VIEW A
ANBOA BODY
Chamberlain
J0152-1


NOTES
NOTE 7
SURFACE B
NOTE 4
VIEW A
FULL SCALE
Chamberlain

J8152-3

REVISIONS				
A	EDR-1			



J8152-3

WEIGHT ZONE			
ZONE	PROJ W/O FUZE-NOTE 4,5		
	OVER	UP TO & INCL	
	POUNDS	POUNDS	
2	90.0	91.3	[illegible]
3	91.1	92.4	[illegible]
4	92.0	93.7	[illegible]
5	93.3	94.6	[illegible]

NOTES:
1 SPEC MIL-A-2550 APPLIES.
2 PAINT BLUE, EXCEPT ROTATING BAND, WITH FIN NO 20.1 OF MIL-STD-171 BLUE NO 35109 (NOTE 8)
3 MARK WITH INK STENCIL WHITE NO 37875
4 SAMPLE WEIGHT ZONE MARKING SHOW PROPER NUMBER OF SQUARES WITH PRICK PUNCH MARK IN CENTER OF EACH SQUARE. PRICK PUNCH MARK SHALL BE OF SUFFICIENT SIZE TO BE DISCERNIBLE BY TOUCH AFTER PAINTING NUMBER OF SQUARES TO CORRESPOND TO WEIGHT IN WEIGHT ZONE TABLE
Ⓐ 5
6 INSERT LOT NUMBER
7 UNTOLERANCED DIMENSIONS NEED NOT BE GAGED
8 BOURRELET SHALL PASS 6.098 MAX DIA RING GAGE
9 WEIGHT APPLIES WITHOUT PLASTIC PLUG AND GROMMET.

PROJECTILE, 155 MM, XM804

Chamberlain

WATERLOO, IOWA

JLM

SCALE NONE

J8152-3

5. XM804 FORGED BODY DEVELOPMENT

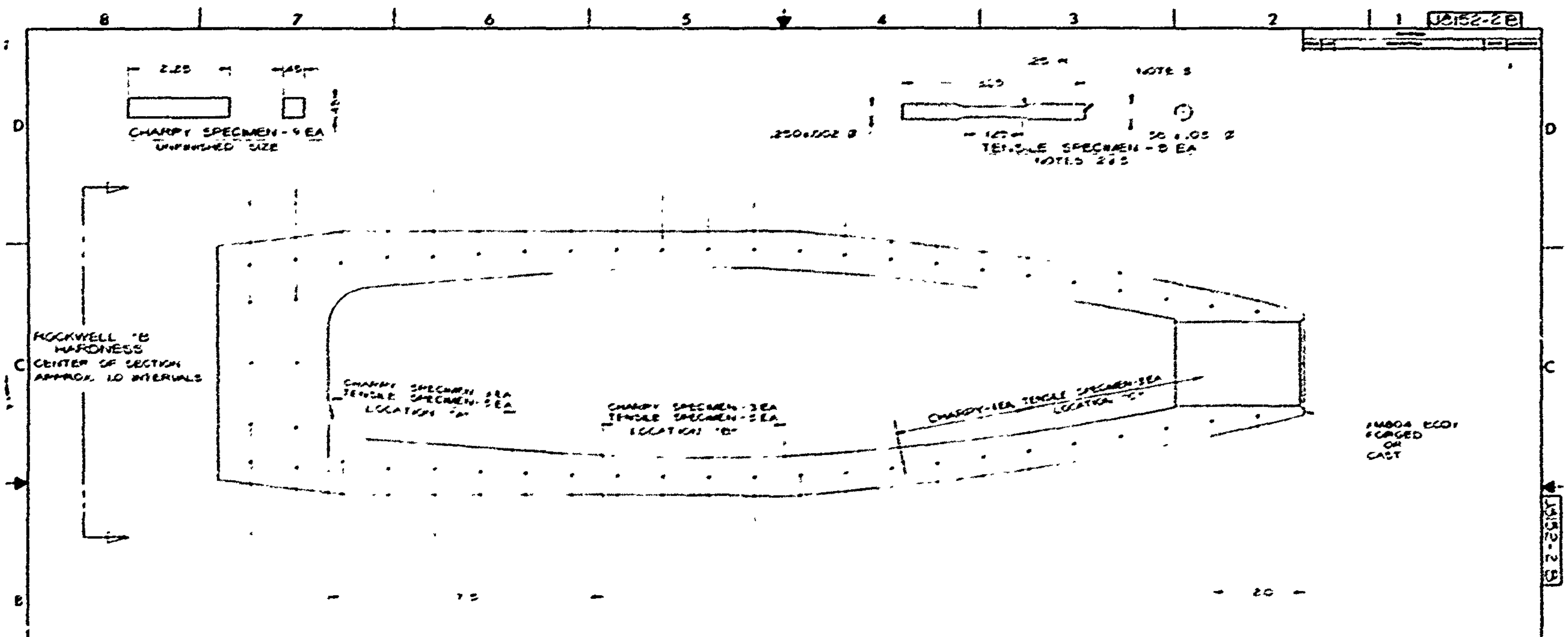
5.1 Manufacture of Bodies

5.1.1 To ensure provision of the required quantity of 300 acceptable XM804 forgings, 400 of these forgings were manufactured at Chamberlain's New Bedford Division under Chamberlain Purchase Order No. B54726, dated 5 May 1978. The process illustrated by the drawings in Appendix A was developed by New Bedford for the manufacture of these projectiles and was based on the design shown by Drawing No. J8152-1 (Rev. A), Page 6. With ARRADCOM's permission, these forgings were manufactured from AISI C1340 steel to eliminate the post heat treatment which would have been necessary to obtain the required physicals with C1046 or C1064 steel. Some difficulty was encountered in developing the nose section contour of the forging to provide the desired interior cavity volume. However, this problem was solved by adjusting the amount of material machined from the open end of the drawn can before nosing. No other problems were encountered in producing these forgings and the quantity of 400 was allocated as follows:

QUANTITY	PROCESS STAGE	DISPOSITION
20	Final-Machined Projectiles	Metal Parts Security Tests
60	Final-Machined Projectiles	Ballistic Match Tests
100	Final-Machined Projectiles	Fuze/Spotter Performance Tests
120	Cold Drawn	Stored at New Bedford for Use in Future
100	Nosed	Used in Nosing Experiments

5.2 Mechanical Properties

5.2.1 The mechanical properties and hardness of a typical XM804 Projectile forged during the program were determined by laboratory analysis and are shown on Drawing Nos. J7952-2B and -3B on the following two pages. The "cold draw" yield strength of the AISI 1340 steel body in the projectile rotating band area ranged from 105,600 to 110,900 psi. According to calculations, the most severe stress encountered by the XM804 during gun firing



TYPE OF BODY	BODY SERIAL NO.	LOC.	AISI 1540 STEEL MECHANICAL PROPERTIES YIELD	TENSILE	ELONG.	CHARPY IMPACT AMBIENT	-40°F
XM804	N.B. #1	A	[illegible]	[illegible]	12.5%	[illegible]	[illegible]
			[illegible]	[illegible]	12.5%		[illegible]
			—	[illegible]	12.4%		[illegible]
		B	[illegible]	[illegible]	16.5%	[illegible]	[illegible]
			[illegible]	[illegible]	18.6%		[illegible]
			[illegible]	[illegible]	18.6%		[illegible]
			[illegible]	[illegible]	12.7%		
		C	[illegible]	[illegible]	13.0%		[illegible]
			[illegible]	[illegible]	12.5%		

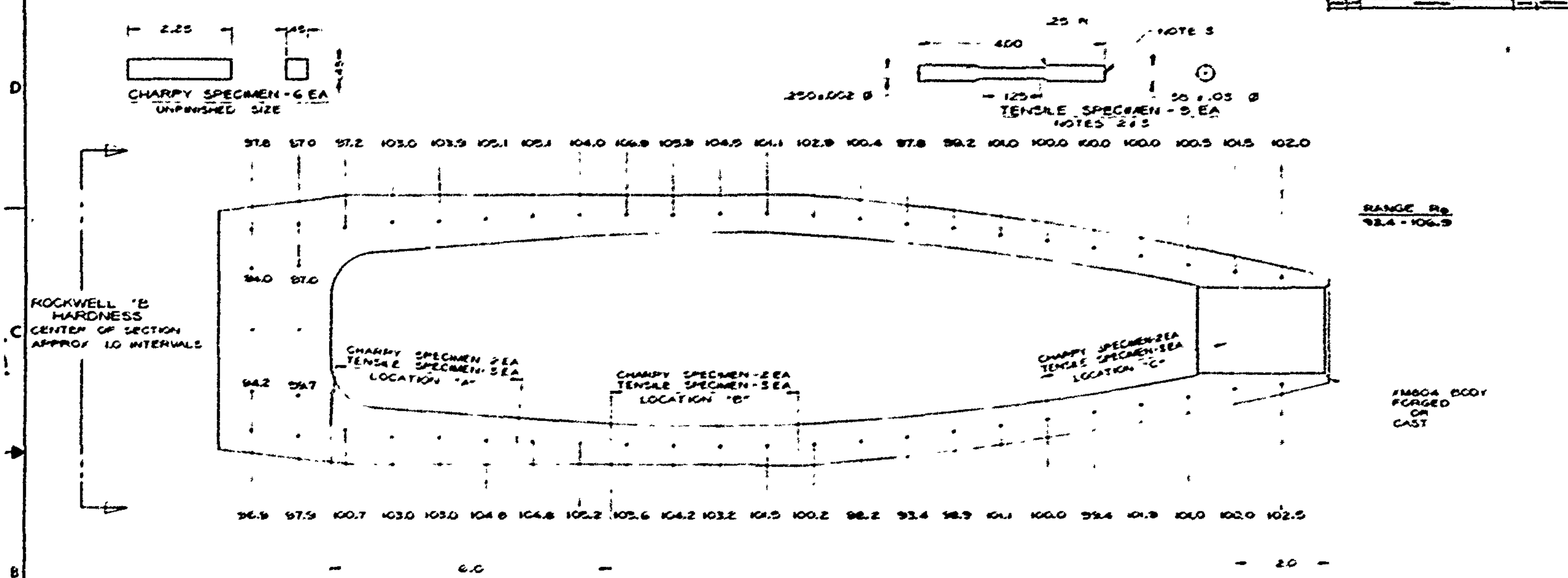
CHEMICAL COMPOSITION ELEMENT	%	AISI 1540 LIMITS
C	0.43	[illegible]
Mn	1.79	[illegible]
P	[illegible]	[illegible]
S	[illegible]	[illegible]
Si	0.20	[illegible]

NOTE:
SEE MATERIAL CERT. FOR REMAINING STEEL HEAT [illegible].

NOTES.
1- SPEC MIL-A-2550 APPLIES
2- TENSILE SPECIMENS ARE TO BE TAKEN RADIALLY ADJACENT TO INDICATED AREA OF HARDNESS PATTERN
3- CENTERDRILL BOTH ENDS TO OBTAIN A CYLINDRICAL REDUCED (.250 DIA) SECTION.
4 N.B. #1 - FIRST XM804 SAMPLE RECEIVED FROM NEW BEDFORD ON 16 JULY 1976 (MIL SECURITY/BALLISTIC MATCH LOT)

Chamberlain	
XM804 BODY MAT'L PROPERTIES	
1540 STEEL	AS CAST OR FORGED
D 86125	J8152-1 B

J8152-2 B



TYPE OF BODY	BODY SERIAL NO.	LOC	AISI 1540 STEEL MECHANICAL PROPERTIES YIELD	TENSILE	ELONG	CHARPY IMPACT AMBIENT	-45°F.
FORGED	N.B. #2	A					
		B					
		C					

CHEMICAL COMPOSITION ELEMENT	%	AISI 1540 ELEMENTS
C	0.43	0.36-0.44
Mn	1.22	[illegible]
P	0.018	0.040 MAX
S	0.018	0.050 MAX
Si	0.24	[illegible]

NOTE.-
SEE MATERIAL CERT. FOR REPUBLIC STEEL HEAT NO. 5464682.

NOTES.
1-SPEC MIL-A-2550 APPLIES
2-TENSILE SPECIMENS ARE TO BE TAKEN RADIALLY ADJACENT TO INDICATED AREA OF HARDNESS PATTERN.
3-CENTERDRILL BOTH ENDS TO OBTAIN A CYLINDRICAL REDUCED (.250 ⌀) SECTION.
4 N.B. #2- SECOND XM804 SAMPLE RECEIVED FROM NEW BEDFORD ON 28 JULY 1976 (MPTS SECURITY/ BALLISTIC MATCH LOT.)

MATERIAL	1540 STEEL AS CAST OR FORGED
DRAWN	JLM
	Chamberlain
TITLE	XM804 BODY MAT'L PROPERTIES
SIZE / CODE IDENT / DWG NO	D 86125 J8152-3 B
	C072

tests was 33,800 psi under Charge, Zone 5 firing conditions. Therefore, the strength of the projectile body in the rotating band area is sufficient to withstand the specified Charge, Zone 5 gun firing environment with a wide margin of safety. As further evidence of the projectile's strength, this analysis also included gun environments up to Charge, Zone 7. The results indicated that the projectile also would withstand this severe environment and subsequent gun firing tests at Charge, Zone 7 confirmed these results. Appendix B contains data from a stress analysis performed on the XM804 Projectile during this program.

6. PRESSURE-CAST XM804 BODY DEVELOPMENT

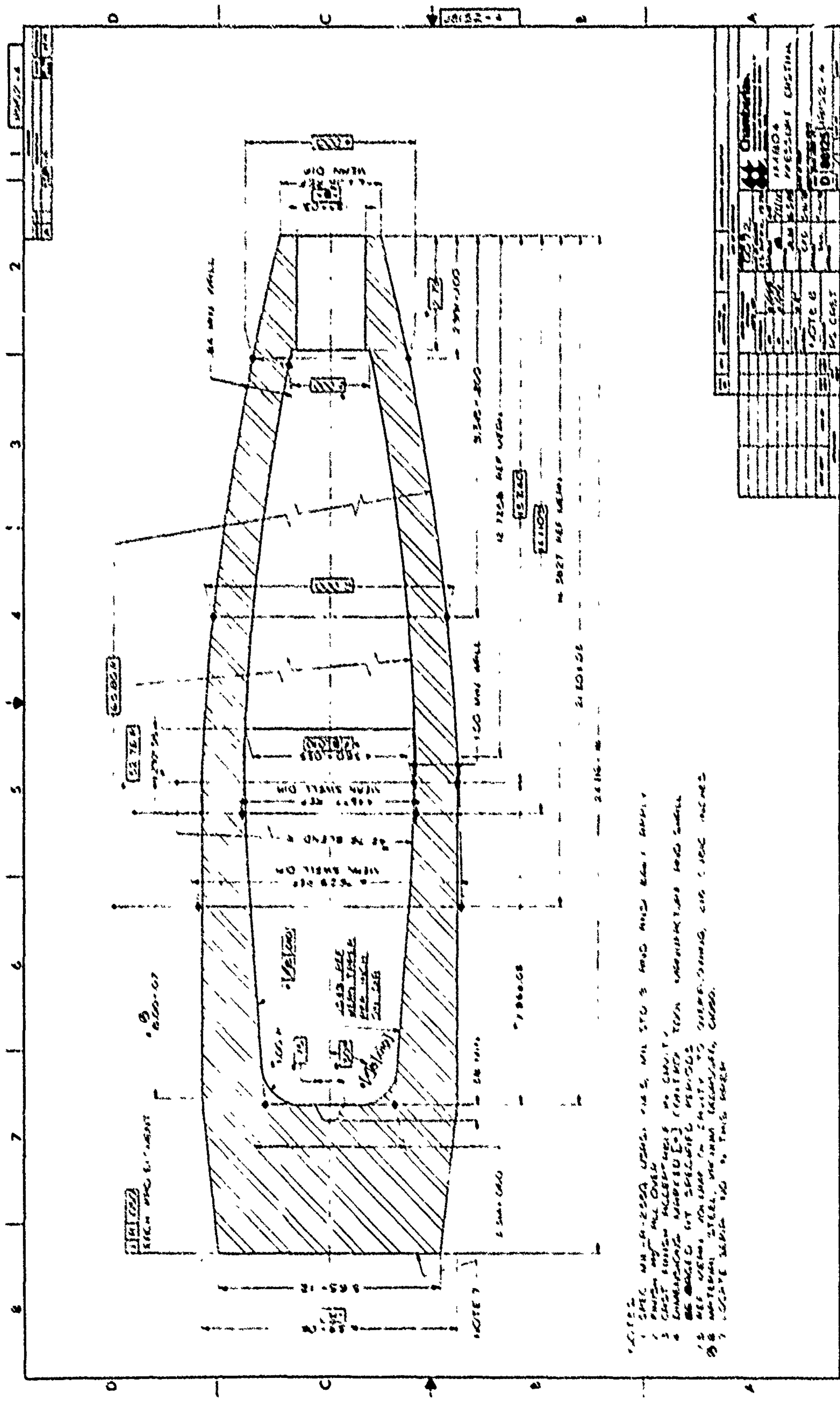
6.1 General

6.1.1 The pressure casting method was selected for the manufacture of the cast XM804 Projectile, the design of which is shown by Drawing No. J8152-4 (Rev. A) on the following page. This method has been used successfully as an economical method of manufacturing a variety of non-ferrous parts but, to the best knowledge of ARRADCOM and Chamberlain personnel, has not been used to produce ferrous items as large as the XM804. The high risk of the pressure casting method was recognized mutually by ARRADCOM and Chamberlain personnel, but it was agreed that the feasibility of this concept should be investigated during the performance of the subject contract because of indications that this method could be developed into a lower cost method of producing the XM804 round (See Cost Estimates, Section 8). On May 1978, Chamberlain Purchase Order No. B54641 was issued to Reynolds Engineering, Inc., Saratoga, California, to pressure-cast 50 each XM804 bodies. This work was performed with Reynolds' equipment at Vulcan Foundry, Oakland, California, with some materials and services being purchased from Vulcan.

6.2 Process Description

6.2.1 Photograph No. C3283, Page 15, shows an overall view of a pressure-casting machine, designed and developed by Reynolds Engineering, which was used to pressure-cast the XM804 body. The XM804 mold, core box and cores were manufactured by Reliable Pattern and Foundry, San Jose, California. An open view of the water-cooled, split aluminum mold (with a core in place) mounted on the casting machine is shown by Photograph No. C3284, Page 16, and typical cores are shown by Photograph No. C3285, Page 17.

6.2.2 Figure 1, Page 18, shows a schematic of the previously-described casting machine. Initially, the mold is swung away from the machine and a cover containing an observation hole is installed over the crucible in place of the feed tube shown in the schematic. The metal is heated and maintained at a temperature of approximately +2,900°F in the crucible with the induction heating coils. The metal temperature is monitored frequently by a device which is thrust into the molten metal. Samples for carbon analysis are obtained by a glass tube with a rubber bulb. A vacuum pump system evacuates trapped gas and air from the molten metal. When the metal is free of air and gases, as evidenced by cessation of turbulence in the metal, the cover is removed, the feed tube is installed, and the



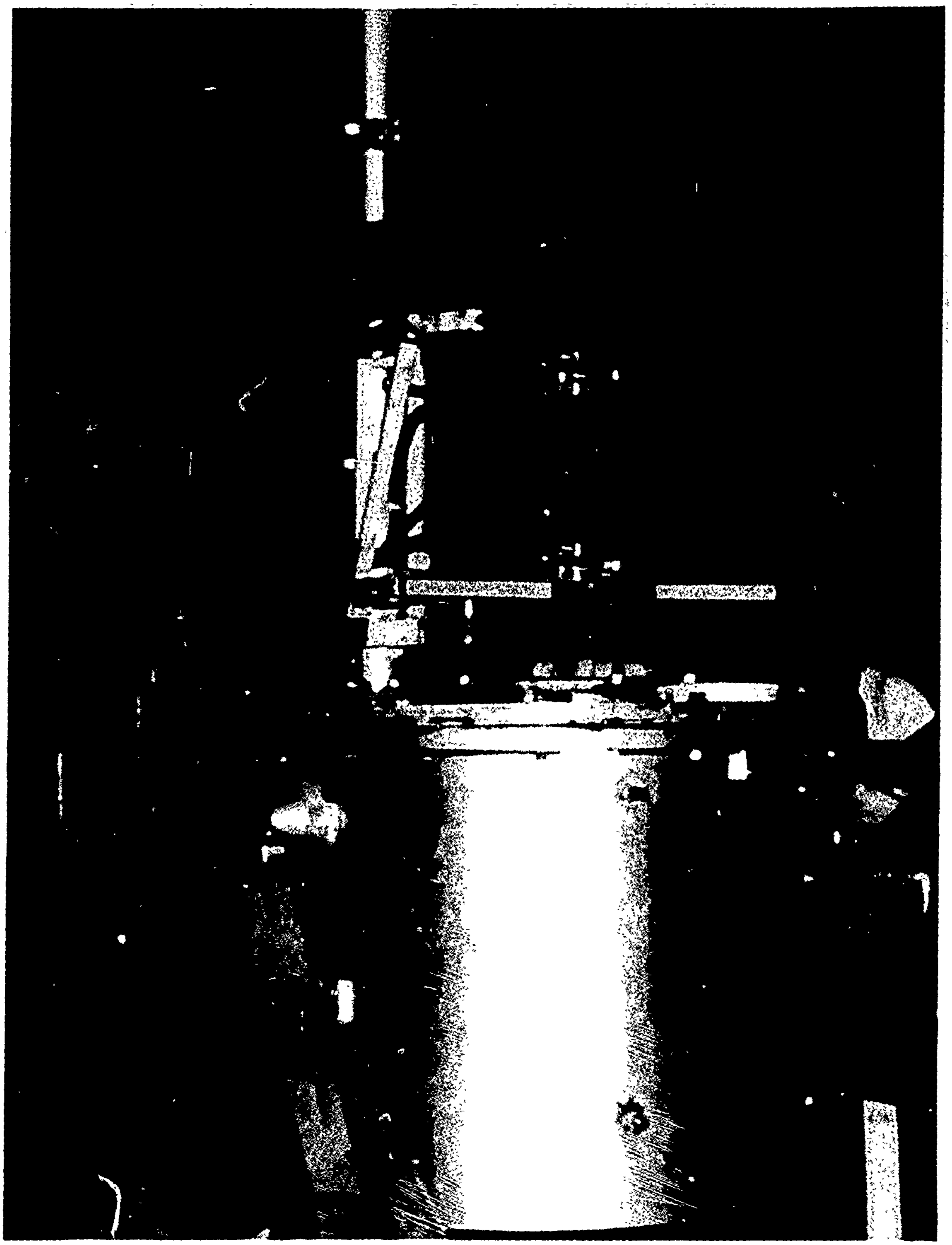


PHOTO NO. C-3283

OVERALL VIEW OF PRESSURE-CASTING MACHINE USED TO PRODUCE THE 155-MM CAST XM804 TRAINING ROUND.

Chamberlain

Chamberlain Manufacturing Corporation

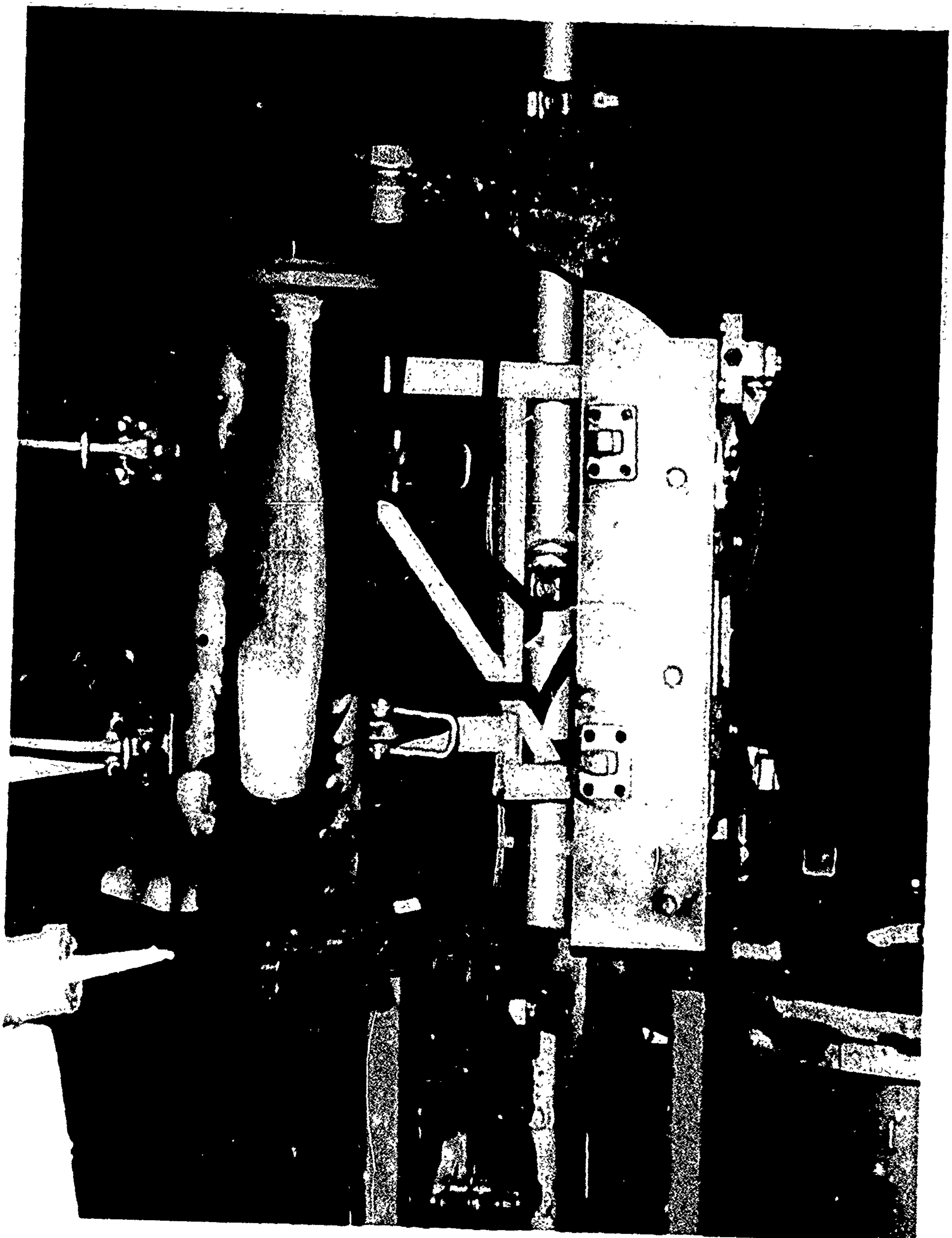


PHOTO NO. C-3284

OPEN VIEW OF TWO-PART ALUMINUM MOLD USED FOR PRESSURE-CASTING THE 155-MM, XM804 TRAINING ROUND.

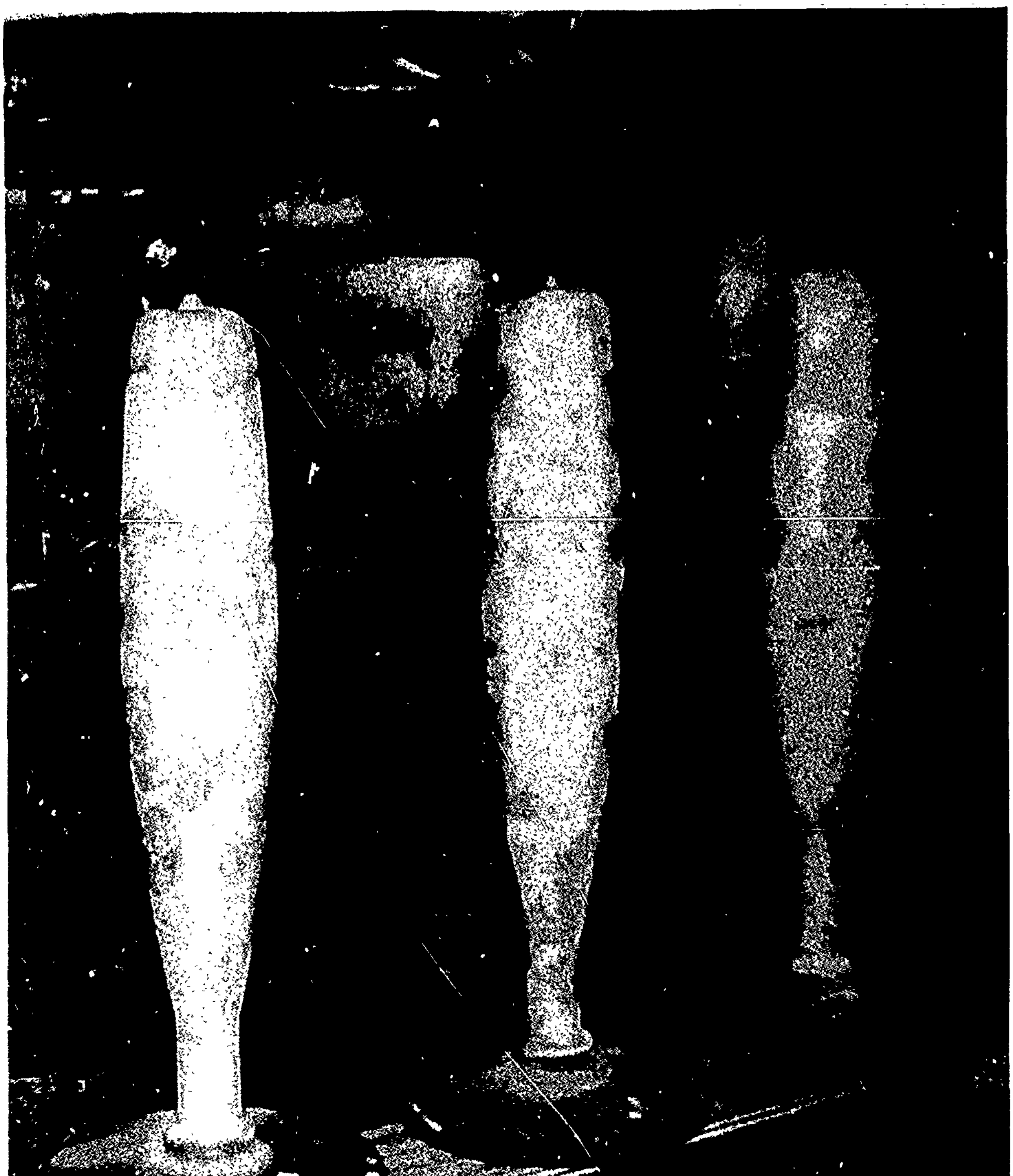


PHOTO NO. C-3285

CORES FOR PRESSURE-CAST, 155-MM, XM804 TRAINING ROUND.

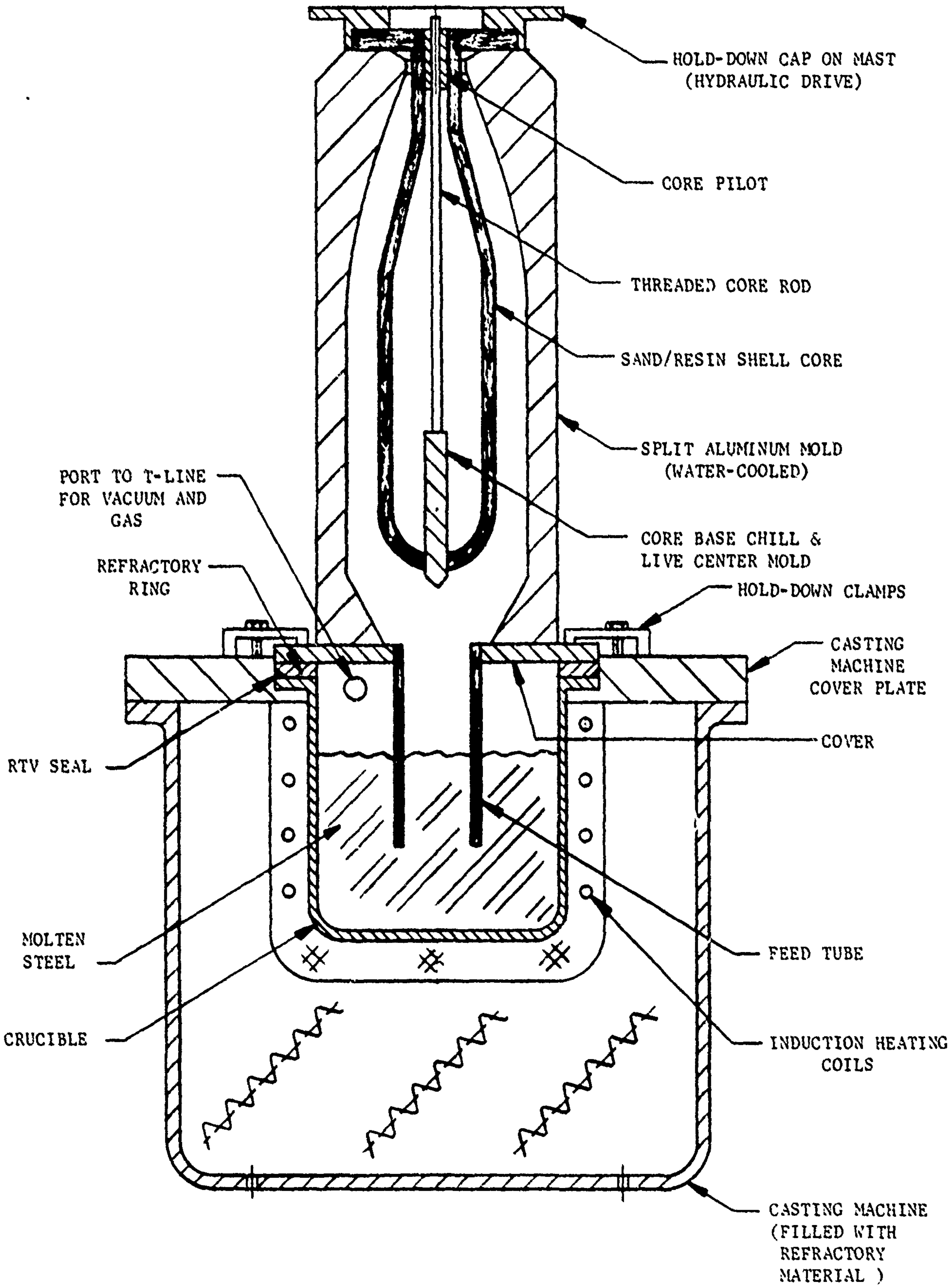


FIGURE 1: Schematic of Reynolds Pressure Casting Machine.

mold is set in position. The molten metal then is forced upward through the feed tube into the water-cooled mold under 12 psi inert (argon) gas pressure, which is applied for from five to six minutes to assure complete filling of the mold. During this cycle, the resin in the core is burned out by the hot metal, leaving only the core sand with the casting. Pressures which are generated within the mold are vented through the porous core and the parting line in the two-piece mold. The argon gas pressure which forces the molten metal into the mold then is released, allowing the molten metal remaining in the feed tube to return to the crucible. The mold is swung away from the machine on the mast, the mold is parted, and the casting is removed. Immediately upon removal, the casting is placed in an insulated barrel to retard cooling, thereby avoiding cracking and brittleness. After the casting has cooled, the residual core sand is emptied through the nose opening.

6.2.2.1 In conducting the above process the following variables were noted which would require further resolution prior to establishing a production process:

- Temperature of the molten metal at time of mold filling.
- Duration of the 12 psi mold filling pressure to assure solidification of metal in casting.
- Amount of vacuum required to evacuate trapped air and gases from the molten metal.
- Chill size and cooling rates/temperature.

6.2.3 The casting machine feed tube is a special refractory, selected for its thermal shock resistance and impermeability. It is preheated to approximately 2000°F to reduce the thermal shock when it is inserted into the molten steel. The interior of the aluminum mold and the exterior of the sand core are prepared for casting by painting with a mold paint which contains zirconium in an alcohol base. The painted surfaces are dried with an acetylene torch immediately after painting and the mold subsequently is carbon-coated by decreasing the oxygen supply to the torch. The purpose of the paint is to cushion the mold and core, while the carbon coating is used to provide lubrication.

6.3 Pressure-Casting of XM804 Bodies

6.3.1 Beginning with a lengthy search required to find a suitable foundry facility, many time-consuming problems were encountered in setting up equipment and manufacturing the initial quantity of castings. Before beginning operation, a complete overhaul of the casting machine and instrumentation was necessary. During a preliminary warm-up period, the machine's resistance heaters failed, necessitating extensive disassembly to gain access to the heaters and subsequent reassembly. The resistance heaters were replaced with induction heaters as part of this repair.

6.3.2 Several trial bodies were cast in attempts to produce bodies which were completely formed. Original plans under this program required procurement of 50 each cast XM804 Projectiles to be allocated as follows:

QUANTITY	ALLOCATION
30	Laboratory Tests (Structural, Metallurgical and Dimensional)
10	Gun-Fired Metal Parts Security
10	Gun-Fired Ballistic Match

However, the problems discussed heretofore prevented the completion of the original plans. Toward the end of the contract period, 19 each XM804 castings were received by Chamberlain. Each of these castings was completely formed except for the base defect shown by Figure 2 on the following page. Typical castings from this group are shown by Photograph No. C3330 on Page 22. To provide cast XM804 Projectiles for testing, five of the above 19 bodies were salvaged by cutting out the area around the base defect and inserting a steel plug which was secured in place by welding as shown by Drawing No. J8152-5, Page 23. Photograph No. C3331, Page 24, shows this plug being inserted in the projectile base. One body in which a nose defect was found was cut for tensile specimens and analysis.

One other body was scrapped when radiographic inspection revealed severe voids in the projectile walls. Three completed projectiles were shipped to Yuma Proving Ground to be gun-fired for structural tests. All three projectiles had interior cavities that were not concentric with the exterior surface, a condition which precluded any ballistic match testing. This "out of balance" condition, however, would not influence metal parts security (structural) tests.

6.3.3 Before producing the next group of castings, possible causes of the base defect were investigated. The first approach was to shorten the core chill from 12 inches to six inches. Several sample bodies were cast using the shorter chill but the base defect still was present. One body

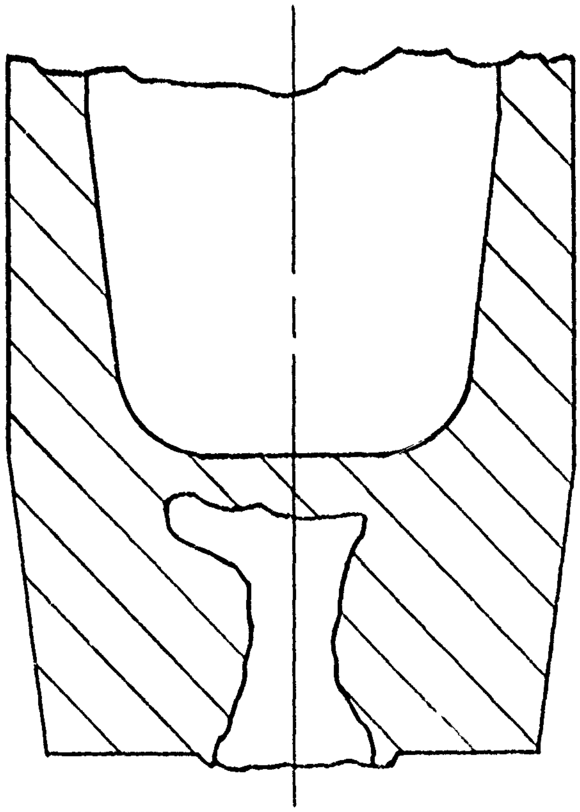


FIGURE 2: Representative Sketch of Base Defect in XM804 Pressure Castings

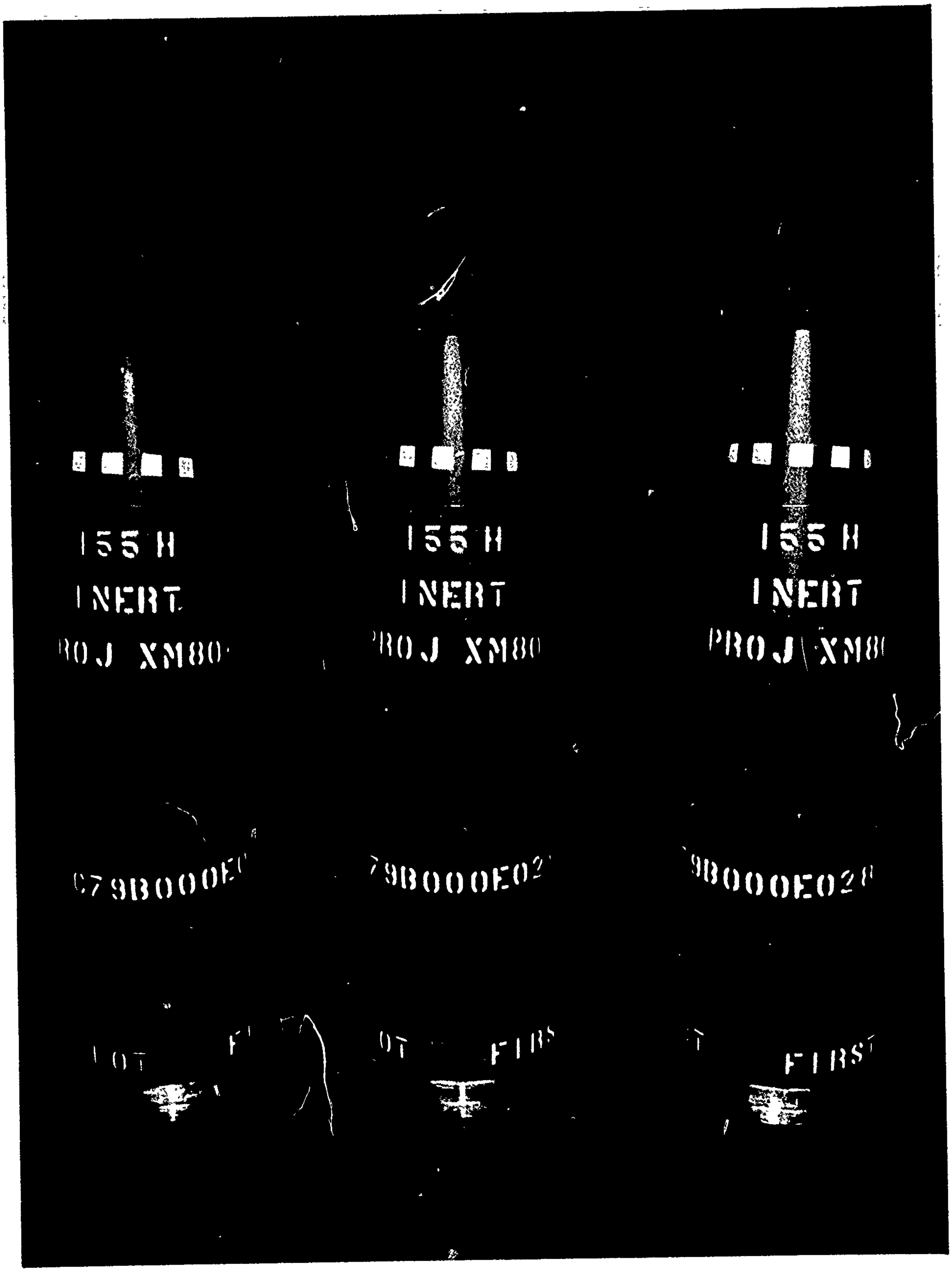
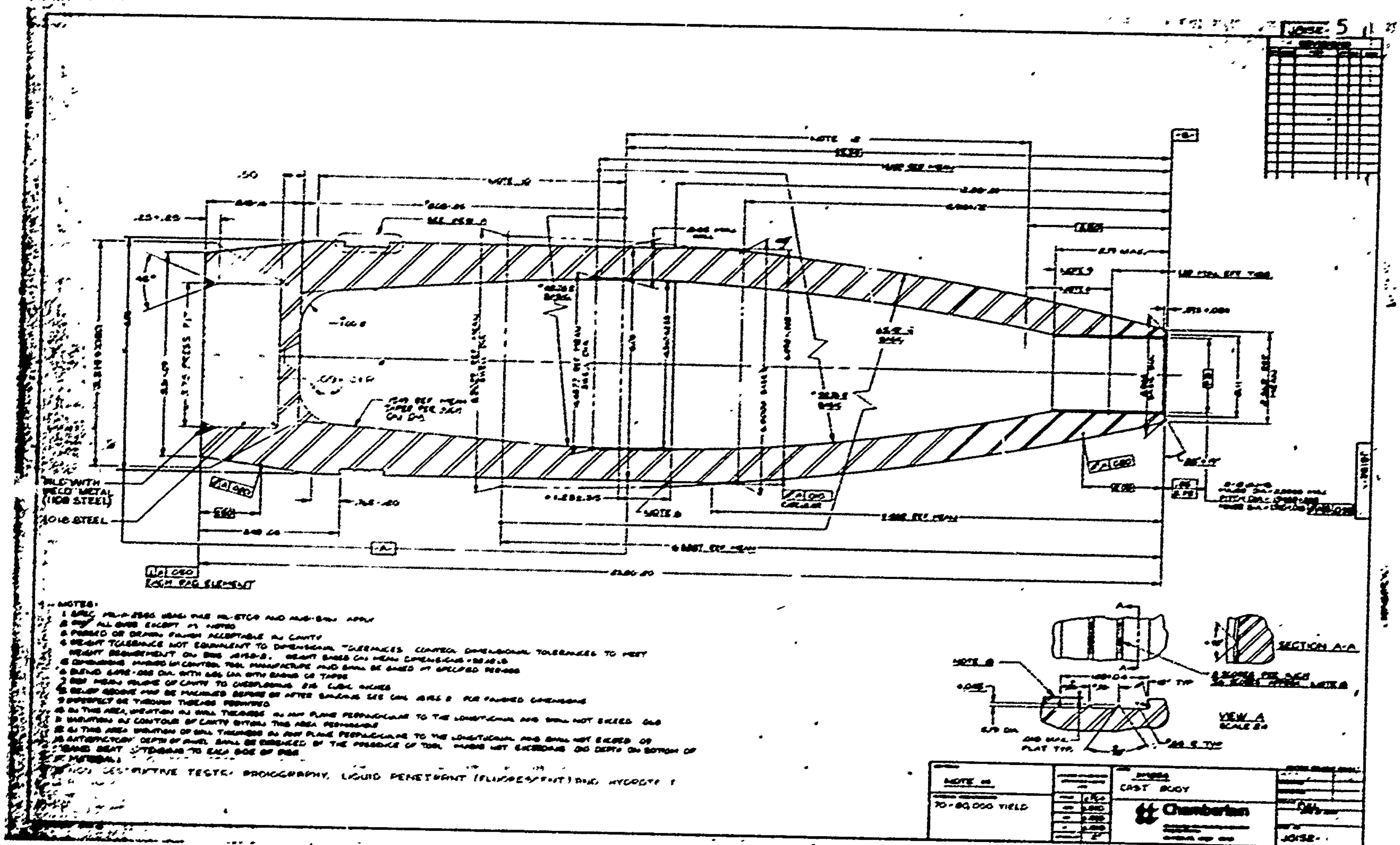


PHOTO NO. C-3330

PRESSURE - CAST 155-MM, XM804 TRAINING ROUNDS.



SECTION A-A
VIEW A
CAST BODY
70-80,000 YIELD
Chamberlain
1018 STEEL
(1108 STEEL)
NOTES:
LIQUID PENETRANT

J8152-5

PHOTO NO. C-3331
PLUG BEING INSERTED IN BORED BASE OF PRESSURE - CAST 155-MM, XM804 TRAINING ROUND TO CORRECT BASE DEFECT.

was cast without using the chill but the base of this body failed to solidify. Later, it was theorized that the base defect and base porosity resulted from gas entering the casting at this point during mold filling. To identify and correct this leakage, the original casting machine feed tube, which was potted into the plate, was replaced by a feed tube which had a flange at its interface with the mold. All of the castings produced with this revised feed tube were free of base defects. These experiments resulted in the conclusion that the critical factor in eliminating the base defects in these projectiles was the feed tube. A further conclusion was that a core chill was required but satisfactory castings would be produced with either the six-inch or the 12-inch long chill.

6.3.4 At the end of the contract period, 30 castings were received from reynolds; 20 of which had solid bases. Although the problem with the base defect was solved, the preliminary X-ray photographs of the raw castings indicated that the sidewalls still contained some voids. These voids could be the result of gas bubbles and/or non-uniform solidification shrinkage. Additional experimentation will be required to determine the cause of these voids and to develop a satisfactory solution. Possibly, wall voids are acceptable in the cast XM804 Projectile and this determination can be made by firing the three rounds which were stored at Yuma Proving Ground at the time this report was written.

7. DYNAMIC TESTING

7.1 Forged XM804 Projectiles

7.1.1 On 12 through 14 September 1978, 65 each XM804 Projectiles with forged bodies (Round Nos. 1 through 65) were fired dynamically at Yuma Proving Ground (YPG). All projectiles were fabricated according to Drawing No. J8152-3, Rev. A, on Page 8 and were shipped to YPG on 30 June 1978 as Lot CG078G001001. All projectiles were fired from the 155-mm, M109A1 Weapon system under the conditions described in the tabulation on the following page. A quantity of 20 each (Round Nos. 1 through 20) were fired in metal parts security tests and the remaining 45 (Round Nos. 21 through 65), in combined ballistic match and metal parts security tests as described in the following paragraphs. The tests were witnessed by representatives of ARRADCOM, Ft. Sill (Oklahoma) Artillery Training School, and Chamberlain R&D.

7.2 Metal Parts Security Tests

7.2.1 All 20 rounds were fired at Charge, Zone 5 and were recovered from an impact area of approximately 200 square meters as determined by gun crew observers. Preliminary data obtained at the Proving Ground are tabulated on Page 28. All 20 rounds were structurally sound when recovered and all rotating bands had remained in place. The rounds had sustained only minor damage upon impact. Half of these rounds were tested with live M739 spotter fuzes but it was not known at the time of this writing whether the fuze signature (flash) was observable upon ground impact. Based on the results of this test, it was concluded that the XM804 Projectile with forged body would survive the Charge, Zone 5 gun firing training environment.

7.3 Ballistic Match/Metal Parts Security Test

7.3.1 Round Nos. 21 through 65 were fired at Charge, Zones 1, 2 and 7 as indicated by the data on Pages 29 through 31. The chief purpose of these tests was to determine the ballistic similitude between the 155-mm, XM804 Projectile and the standard 155-mm, M107 Projectile for which the XM804 was to be a ballistic match. An additional purpose was to determine the metal parts security of the XM804 Projectile in the Charge, Zone 7 firing environment. Preliminary data obtained from these tests at the Proving Ground are included on Pages 29 through 31. The muzzle velocity and range of the XM804 Projectile compared closely to the muzzle velocity and range of the standard

TEST CONDITIONS AND HARDWARE

XM804 PROJECTILE - DRAWING NO. J8152-3

Lot CG078G001001

TEST	WEAPON SYSTEM AND SERIAL NOS.	QUADRANT ELEVATION (Mils)	CHARGE ZONE	RDS. FIRED	PROPELLANT	TEMPERATURE CONDITIONING	CAMERA SET-UP
MPTS Security (20 ea.)	M109A1 Carriage #12014468 M185 Gun #1913 M185 Tube #23252	750	5	20 ea.	M3A1 (Lot R&D67623)	Ambient	Smear @ 90° & Framing behind gun
Ballistic Match (45 rds.)	M109A1 Carriage #12014468 M185 Gun #1913 M185 Tube #23252	350	1	5 Ea.	M3A1	Ambient	Smear @ 90° & Framing behind gun
		350	2	5 Ea.	M3A1		
		350	7	5 Ea.	M4A2		
		750	1	5 Ea.	M3A1	Ambient	"
		750	2	5 Ea.	M3A1		
		750	7	5 Ea.	M4A2		
		1150	7	5 Ea.	M4A2	Ambient	No Camera Coverage
		1150	1	5 Ea.	M3A1		
		1150	2	5 Ea.	M3A1		

XM804 METAL PARTS SECURITY TEST DATA

TEST RD. NO.	QUADRANT ELEVATION (Mils)	MUZZLE VELOCITY (FPS)	CHARGE ZONE	PROJECTILE WT. (W/O FUZE) (Lbs.)	FUZE MODEL
T-1	750	1229	5	92.5	M78
T-2	750	1229	5	92.7	M78
T-3	750	1228	5	92.6	M78
T-4	750	1224	5	93.2	M78
T-5	750	1229	5	92.4	M78
T-6	750	1223	5	93.1	M78
T-7	750	1223	5	93.1	M78
T-8	750	1231	5	92.0	M78
T-9	750	1229	5	92.4	M78
T-10	750	1229	5	92.2	M78
T-11	750	1226	5	93.5	M739 (30°)
T-12	750	1228	5	93.4	M739 (30°)
T-13	750	1236	5	92.3	M739 (30°)
T-14	750	1229	5	93.2	M739 (30°)
T-15	750	1234	5	92.6	M739 (30°)
T-16	750	1233	5	92.4	M739 (90°)
T-17	750	1237	5	92.4	M739 (90°)
T-18	750	1232	5	92.7	M739 (90°)
T-19	750	1232	5	92.7	M739 (90°)
T-20	750	1230	5	93.2	M739 (90°)

REMARKS

a. Muzzle Velocity Range: 1223-1237 FPS/ 20 Rds.

b. All rounds impacted in an area 200 meters x 200 meters.

c. All (20 ea.) Rounds recovered.

d. Average muzzle velocity = 1229.55 FPS.

XM804 BALLISTIC MATCH TEST DATA

TEST RD. NO.	QUADRANT ELEVATION (Mils)	MUZZLE VELOCITY (FPS)	CHARGE ZONE	PROJECTILE WT. (W/O FUZE) (Lbs.)	FUZE MODEL	REMARKS
T-21	350	644	1	92.5	M557	Muzzle velocity range:
T-22	350	645	1	92.9	M557	642-645 FPS/5 rds.
T-23	350	642	1	93.0	M557	Avg. muzzle velocity:
T-24	350	642	1	93.2	M739 (30°)	= 643.4 FPS
T-25	350	644	1	92.5	M739 (30°)	
T-26	350	744	2	93.5	M557	Muzzle velocity range:
T-27	350	744	2	92.5	M557	744 - 753 FPS/5 rds.
T-28	350	748	2	92.6	M557	Avg. muzzle velocity:
T-29	350	752	2	93.1	M739 (90°)	= 748.2 FPS
T-30	350	753	2	92.2	M739 (90°)	
T-31	350	1844	7	93.1	M557	Muzzle velocity range:
T-32	350	1843	7	93.1	M557	1842 - 1857/5 rds.
T-33	350	1842	7	93.1	M557	Avg. muzzle velocity:
T-34	350	1847	7	93.4	M739 (30°)	= 1846.6 FPS
T-35	350	1857	7	92.7	M739 (90°)	

XM804 BALLISTIC MATCH TEST DATA

TEST RD. NO.	QUADRANT ELEVATION (Mils)	MUZZLE VELOCITY (FPS)	CHARGE ZONE	PROJECTILE WT. (W/O FUZE) (Lbs.)	FUZE MODEL	REMARKS
T-36	750	645	1	92.7	M557	Muzzle velocity range:
T-37	750	662	1	92.0	M557	645 - 664 FPS/5 rds.
T-38	750	658	1	93.0	M557	Avg. muzzle velocity:
T-39	750	660	1	92.7	M739 (30°)	= 657.8 FPS
T-40	750	664	1	93.1	M739 (30°)	
T-41	750	759	2	92.6	M557	Muzzle velocity range:
T-42	750	759	2	93.1	M557	757 - 761 FPS/5 rds.
T-43	750	757	2	93.3	M557	Avg. muzzle velocity:
T-44	750	761	2	92.7	M739 (30°)	= 759.4 FPS
T-45	750	761	2	93.2	M739 (90°)	
T-46	750	1851	7	93.0	M557	Muzzle velocity range:
T-47	750	1845	7	93.2	M557	1845-1856 FPS/5 rds.
T-48	750	1846	7	92.6	M557	Avg. muzzle velocity:
T-49	750	1852	7	93.1	M739 (30°)	= 1850.0 FPS
T-50	750	1856	7	92.6	M739 (90°)	

XM804 BALLISTIC MATCH TEST DATA

TEST RD. NO.	QUADRANT ELEVATION (Mils)	MUZZLE VELOCITY (FPS)	CHARGE ZONE	PROJECTILE WT. (W/O FUZE) (Lbs.)	FUZE MODEL	REMARKS
T-51	1150	1842	7	93.0	M557	Muzzle velocity range:
T-52	1150	1846	7	92.7	M557	1842 - 1854 FPS/5 rds.
T-53	1150	1845	7	92.6	M557	Avg. muzzle velocity:
T-54	1150	1847	7	93.1	M557	= 1846.8 FPS
T-55	1150	1854	7	92.8	M739 (30°)	
T-56	1150	640	1	92.4	M557	Muzzle velocity range:
T-57	1150	672	1	92.2	M557	640 - 686 FPS/5 rds.
T-58	1150	675	1	92.8	M557	Avg. Muzzle velocity:
T-59	1150	685	1	93.5	M557	= 671.6 FPS
T-60	1150	686	1	92.6	M739 (30°)	
T-61	1150	777	2	93.6	M557	Muzzle velocity range:
T-62	1150	774	2	92.8	M557	768 - 777 FPS/5 rds.
T-63	1150	772	2	93.0	M557	Avg. muzzle velocity:
T-64	1150	768	2	93.2	M557	= 773.0 FPS
T-65	1150	774	2	93.1	M739 (90°)	

NOTE: Refer to the "Gunners Firing Record", dated 12 and 14 September 1978, furnished by Yuma Proving Ground for additional minor information.

M107 inert spotter rounds which were fired to verify test parameters. Tentative conclusions based on available information were that the XM804 Projectile should be a ballistic match to the M107 Projectile. Preliminary range and deflection data also showed that the XM804 Projectile remained structurally sound under the Charge, Zone 7 firing environment, which imposes the most severe conditions this projectile is expected to encounter.

7.4 Tests of XM804 Projectile with XM747 Fuze and M107 Projectiles

7.4.1 On 29 January through 8 February 1979, dynamic firings were conducted at Yuma Proving Ground for the following purposes:

- To determine the ballistic similitude between the forged 155-mm, XM804 Projectile and the standard 155-mm, M107 Projectile.
- To test the performance of Hydro-Cal (Inert) Loaded M107 Projectile.
- To observe the performance of the XM747 (Modified M739) Training Fuze.

These fuzes were tested as part of efforts by ARRADCOM to develop a training fuze which would have less critical safe-handling requirements than the existing M739 Fuze. These tests were witnessed by representatives of ARRADCOM, Ft. Sill (Oklahoma) Artillery Training School, and Chamberlain Research and Development Division.

7.4.2 Following is a description of the projectiles which were tested:

QUANTITY	TYPE	LOT NO.
115	Forged XM804 Projectiles (Drawing No. J8152-3, Rev. A)	CG078G001001
139	Standard Inert-Loaded M107 Projectiles with M577 Fuzes	--
24	"Hydro-Cal"-Loaded M107 Projectiles	YCC78K000E001

The quantity of 24 each M107 Projectiles were manufactured by Chamberlain's Scranton Division under Purchase Order No. B55155, dated 27 September 1978. Subsequently, these projectiles were shipped to Carter-Pol Development Corporation, Moscow, Pennsylvania, where they were inert-loaded with Hydro-Cal under Chamberlain Purchase Order No. B55156, dated 27 September 1978. Hydro-Cal is an inert-load mixture consisting of gypsum in a plastic binder and is reported to be a lower-cost load than the inert wax load which currently is the established inert load for the M107 Projectile. The Hydro-Cal loaded projectiles were included in this test to check

their performance against the wax-loaded version. Following is a description of the modified XM739 Fuzes (designated XM747 Training Fuzes) which were included in this test:

QUANTITY	TYPE	MODIFICATION
27	XM747	Mod. A, SW-59 (Smoke)
37	XM747	Mod. B, SW-466 (Smoke)
40	XM747	Mod. C, SW-521 (Smoke)
30	XM747	Mod. PF, Photoflash

Also included as a control group were five each M577 Fuzes, each of which had a T2 Booster Charge.

7.4.3 The total quantity of rounds was divided into 28 groups which were equipped with various modified fuzes and fired according to the test matrix on the following page. To facilitate comparison of performance, XM804 rounds were fired alternately with standard M107 rounds. The weapon system consisted of the M185 Gun and the M185 Tube mounted on the M109A1 Motor Carriage. To record the flight of every XM804 Projectile, a smear camera was positioned 25 feet from the gun muzzle at a 90° angle to the line of fire. For four of the test groups, 16-mm color movie film coverage was obtained. Also color TV camera coverage was obtained on at least one round from each group.

7.4.4 Preliminary data from the tests of XM804 and M107 Projectiles from Group Nos. 1 through 16 are tabulated on Page 35. Data from the remaining groups (Nos. 17 through 28) were not available at the time this report was written. Tentative conclusions were that the XM804 "heavy wall" projectile and the standard M107 Projectile had adequate ballistic similitude. Firm conclusions will be based on complete data analysis conducted by ARRADCOM's Aero-Ballistic Section in the future. Also based on preliminary data analysis, it was concluded that the M107 Projectiles which were inert-loaded with Hydro-Cal at Carter-Pol Development Corporation would perform successfully during firing at Charge, Zone 5 or below. Proof testing by firing at Charge, Zone 7 is recommended before final acceptance of this round.

7.4.5 Performance of the XM747 Training Fuze was assessed by audio and visual interpretation of the fuze signature upon ground impact of the round. Observations by personnel at the target site were confirmed by TV video tape and 16-mm movie film obtained during the test. The test results of the various fuze configurations are being evaluated by the responsible agencies.

XM804/M107 PROJECTILE TEST MATRIX

AMBIENT TEMP. COND.			GROUP SIZES AND TYPES OF FUZES				
TRAINING PROJECTILE	CHARGE ZONE	PROPELLANT TYPE	Q.E. 350	Q.E. 550	Q.E. 750	Q.E. 950	Q.E. 1100
HEAVY WALL XM804-FORGED	1	M3A1					
" "	2	"	5EA 2C,2B,1PF		6EA 4C,1PF, 1M557		*5EA 1A,1B,2C, 1PF
" "	3	"	5EA-1A, 1B,2C,1PF		6EA-1A, 3C,1PF, 1 M557		5EA-2B, 2C,1PF
" "	3	M4A2			6EA-1A, 3C, 1PF, 1M557		
" "	4	"			6EA-4B, 1PF, 1M557		
" "	5	"	5EA-1A, 2B,1C, 1PF*		6EA-4C, 1PF, 1M557		5EA 4B, 1PF
XM804 W/INERT LOADED M107 BODY	5	"					
+140°F TEMP. CONDITION							
HEAVY WALL XM804 FORGED	1	M3A1	5EA-1A, 2B,1C,1PF*				
" "	2	"	4EA ✓ 3C, 1PF				
" "	3	"		4EA ✓ 2C, 2PF			
" "	3	M4A2			4EA ✓ 2C, 2PF		
" "	4	"					
" "	5	"					
XM804 W/INERT LOADED M107 BODY	5	"		5 EA 4B, 1PF		5 EA 4C, 1PF	
-40°F TEMP. CONDITION							
HEAVY WALL XM804-FORGED	1	M3A1					5EA 4A, 1PF
" "	2	"					
" "	3	"					5EA 4A, 1PF
" "	3	M4A2					
" "	4	"					4EA 3B, 1PF
" "	5	"	5EA 4A, 1PF	4EA 3B, 1PF	5EA 4B, 1PF	5EA 4A, 1PF	*5EA,1A 2B,1C,1PF
XM804 W/INERT LOADED M107 BODY	5	"	4EA 3B, 1PF		5EA 4C, 1PF		5EA 4A, 1PF

*16MM COLOR MOVIE FILM QE-MILS. ✓ = NIGHT TEST

PRELIMINARY DATA FROM TESTS OF
XM804 AND M107 PROJECTILES

(AVERAGE OF GROUPS)

GROUP	TEST DATE	RD TYPE	QE (MILS)	ZONE	PROP. CHG.	AVG. WGT. (LBS)	TEMP.	AVG. MUZZLE VELOCITY (FT/SEC)	AVG. RANGE (METERS)	AVG. DEFLECT (METERS)
1	29 JAN 79	XM804	350	5	M4A2	94.56	+70°F	1273	6,872	23R.
		M107	350	5	M4A2	94.14	+70°F	1271	6,867	23R.
2	29 JAN 79	XM804	1100	2	M3A1	94.72	+70°F	717	3,631	219R.
		M107	1100	2	M3A1	94.18	+70°F	718	3,625	219R.
3	30 JAN 79	XM804	350	1	M3A1	93.36	+140°F	608	2,072	34R.
		M107	350	1	M3A1	94.4	+140°F	614	2,120	44R.
4	30 JAN 79	XM804	1100	5	M4A2	93.32	-40°F	1268	8,210	425R.
		M107	1100	5	M4A2	94.12	-40°F	1259	8,224	385R.
5	30 JAN 79	INERT-LOADED XM804/M107	1100	5	M4A2	95.28	-40°F	1270	8,340	373R.
		M107	1100	5	M4A2	94.56	-40°F	1262	8,252	384R.
6	1 FEB 79	XM804	750	4	M4A2	94.91	+70°F	1079	8,743	111R.
		M107	750	4	M4A2	94.52	+70°F	1075	8,681	67R.
7	1 FEB 79	XM804	750	5	M4A2	94.55	+70°F	1270	10,292	230R.
		M107	750	5	M4A2	94.25	+70°F	1266	10,280	200R.
8	1 FEB 79	XM804	750	5	M4A2	93.02	-40°F	1251	10,080	185R.
		M107	750	5	M4A2	94.28	-40°F	1238	9,998	175R.
9	1 FEB 79	INERT-LOADED XM804/M107	750	5	M4A2	95.46	-40°F	1249	10,080	182R.
		M107	750	5	M4A2	94.30	-40°F	1244	10,017	181R.
10	1 FEB 79	INERT-LOADED XM804/M107	950	5	M4A2	95.48	+140°F	1284	10,156	337R.
		M107	950	5	M4A2	94.44	+140°F	1279	10,088	331R.
11	2 FEB 79	XM804	950	5	M4A2	93.46	-40°F	1251	9,552	202R.
		M107	950	5	M4A2	94.04	-40°F	1235	9,470	246R.
12	2 FEB 79	INERT-LOADED XM804/M107	550	5	M4A2	95.40	+140°F	1284	9,245	0R.
		M107	550	5	M4A2	94.28	+140°F	1280	9,214	12R.
13	2 FEB 79	XM804	1100	5	M4A2	92.86	+70°F	1275	8,555	377R.
		M107	1100	5	M4A2	94.54	+70°F	1266	8,568	344R.
14	2 FEB 79	XM804	1100	4	M4A2	93.45	-40°F	1077	7,125	319R.
		M107	1100	4	M4A2	94.00	-40°F	1061	6,990	295R.
15	2 FEB 79	INERT-LOADED XM804/M107	350	5	M4A2	95.28	-40°F	1259	6,756	9R.
		M107	350	5	M4A2	94.55	-40°F	1240	6,648	5R.
16	2 FEB 79	XM804	350	5	M4A2	93.2	-40°F	1252	6,678	0R.
		M107	350	5	M4A2	94.5	-40°F	1239	6,639	3R.

8. PRODUCTION COST ESTIMATES

8.1 Costing and feasibility studies were conducted on the following four designs:

- Standard M107 round with inert fill.
- Heavy-wall XM804 forging.
- Pressure-cast XM804.
- Sand-cast XM804.

Cost estimates for each of these designs are summarized on the following page and complete details thereof are included in Appendix C. Production cost estimates for the casting process were based on an initial rate of 200,000 projectiles per year for five years (1,000,000 rounds) at current prices considering: unit price, background costs identified, current labor rates, and facilities cost. One of the pressure casting production estimates includes a facility estimate but the facility was omitted from the forging production estimate. The forging cost estimates were to assume current production at Scranton and New Bedford plus the 200,000 XM804 forgings per year. Chamberlain was to establish the optimum yearly quantity of XM804 forgings at each facility. In all cases, the current production levels or facility usages are assumed to exist concurrently with the XM804 production and these conditions would continue to exist over a period of five years (1,000,000 rounds). A cost estimate for the standard M107 Projectile from the New Bedford Division was not obtainable because this round was not being produced at Chamberlain's New Bedford Division at the time of this writing.

8.2 Figures provided by ARRADCOM showed that in 1977 it cost $26.78 to load the standard M107 with explosive and an additional $53.40 for the metal parts not including the fuze. The total 1977 cost for the M107 Projectile and load was $80.18. The forged heavy-wall XM804 average estimated cost (see the next page) in 1978 is $47.34 (43.60 + 51.75 + 46.67)/3. Disregarding all possible escalations, the heavy-wall forging is 59% (47.34/80.18 x 100) of the standard round cost representing a 41% savings. The cast heavy-wall XM804 average estimated cost is $41.53 ($43.13 + $39.92)/2. A cast projectile is 52% (41.53/80.18 x 100) of the standard round representing a 48% savings.

XM804 PRODUCTION COST ESTIMATE SUMMARY

(17,000 RDS/MONTH = 204,000 RDS./YEAR)

(TOOLING COSTS AMORTIZED OVER 1,000,000 RDS.)

DATE OF ORIGINAL ESTIMATE	MANUFACTURING FACILITY, TYPE OF RD. & RATE	$ COST/EA. FOR 1,000,000 RDS.	FORGING COST	MACHINING COST	CASTING COST
6-26-78	CMC NEW BEDFORD, HEAVY WALL PROJECTILE @ 25,000 RDS./MONTH	43.60	32.84	10.76	--
6-26-78	CMC SCRANTON (AAP) HEAVY WALL PROJECTILE @ 17,000 RDS./MONTH @ 22,000 RDS./MONTH	51.75 46.67	37.78 32.70	13.97 13.97	-- --
6-26-78	CMC SCRANTON M107 MODIFIED + $2.37 INERT LOADING @ 17,000 RDS./MONTH @ 22,000 RDS./MONTH	55.44 49.23	41.47 35.26	13.97 13.97	-- --
5-1-78	REYNOLDS ENG. INC. HEAVY WALL CASTING @ 17-22,000 RDS./MONTH @ 25,000 RDS./MONTH	26.82* 23.61*	-- --	13.97 10.76	12.85 12.85
10-17-78	CMC R&D CASTING ESTIMATE--HEAVY WALL @ 17-22,000 RDS./MONTH @ 25,000 RDS./MONTH	43.13θ 39.92θ	-- --	13.97 10.76	29.16 29.16
4-14-77	LYNCHBURG FOUNDRY SAND-CASTING (HEAVY WALL) W/PLUG @ 17-22,000 RDS./MONTH @ 25,000 RDS./MONTH	49.97 MIN. 46.76 MIN.	-- --	>13.97 >10.76	36.00 36.00

*Capital Equipment Costs Included/3.000,000 Rds.

θFacility Costs Not Included

APPENDIX A

XM804 FORGED PROJECTILE PROCESS DRAWINGS

CHAMBERLAIN Manufacturing Corporation
NEW BEDFORD DIV.

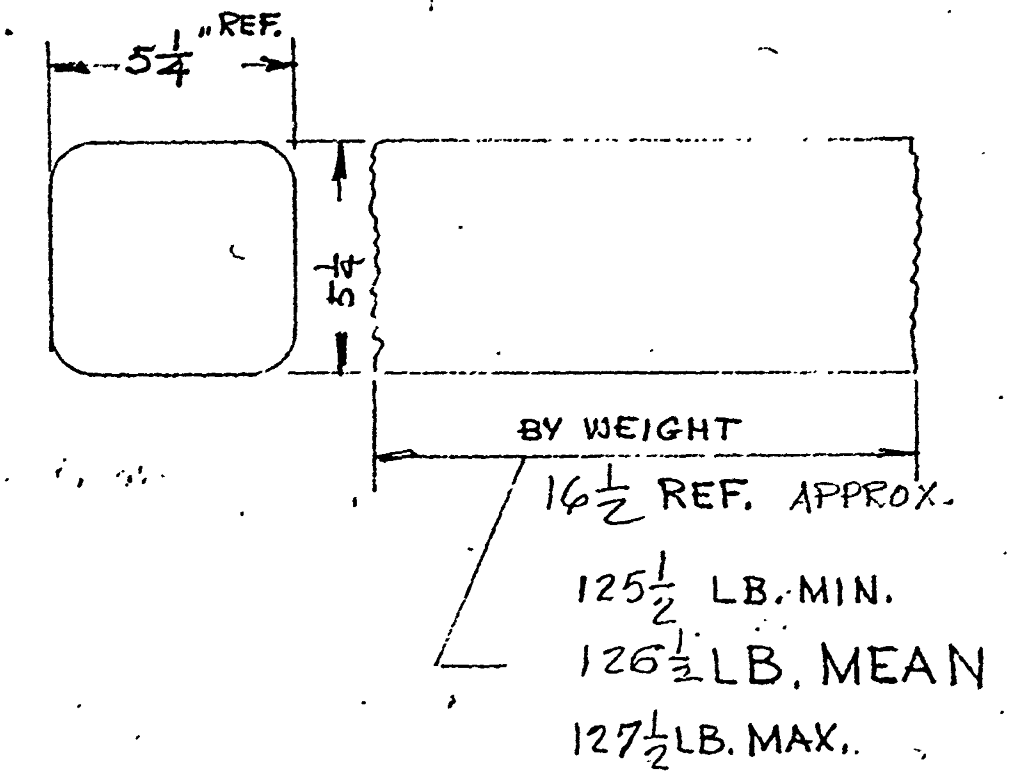
TYPE OF MACHINE	JOB	
20 TON YARD CRANE	BODY, XM804 155MM SHELL	
ACCOUNT NO.	DRAWING NO.	OPERATION NO.
	J8152	5

MAT'L - STEEL BARS

BRING BILLETS ONTO BILLET SHEAR TABLE

LET.	REVISIONS	DATE	BY					DWG. DATE	SHEET
								5-4-78	1 OF 1

CHAMBERLAIN Manufacturing Corporation NEW BEDFORD DIV.	TYPE OF MACHINE BUFFALO SHEAR	JOB BODY. XM804 155MM SHELL	
	ACCOUNT NO.	DRAWING NO. J8152	OPERATION NO. 10



SHEAR BILLET

LET.	REVISIONS	DATE	BY	DWG. DATE	SHEET
				5-4-78	1 OF 1

CHAMBERLAIN Manufacturing Corporation NEW BEDFORD DIV.	TYPE OF MACHINE	JOB BODY, XM804 155MM SHELL	
	ACCOUNT NO.	DRAWING NO. J8152	OPERATION NO. 15

MAT'L - STEEL BARS

LOAD BILLET CONVEYOR

LET.	REVISIONS	DATE	BY					DWG. DATE	SHEET
								5-4-78	1 OF 1

CHAMBERLAIN Manufacturing Corporation NEW BEDFORD DIV.	TYPE OF MACHINE	JOB BODY, XM804 155MM SHELL	
	ACCOUNT NO.	DRAWING NO. J8152	OPERATION NO. 20

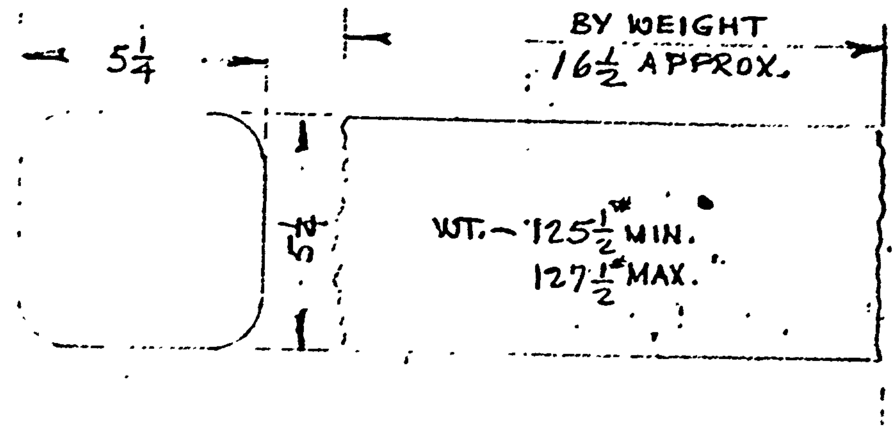
MAT'L- STEEL FORGING

UNLOAD BILLET CONVEYOR
LOAD FURNACE CONVEYOR

LET.	REVISIONS	DATE	BY					DWG. DATE	SHEET
								5-4-78	1 OF 1

CHAMBERLAIN Manufacturing Corporation, NEW BEDFORD DIV.	TYPE OF MACHINE: BILLET HEATING FURNACE 22' ROTARY	JOB: BODY: XM804 155MM SHELL	
	~~ACCOUNT NO.~~ LEE WILSON	DRAWING NO. J8152	OPERATION NO. 10-25

MAT'L- STEEL BILLET

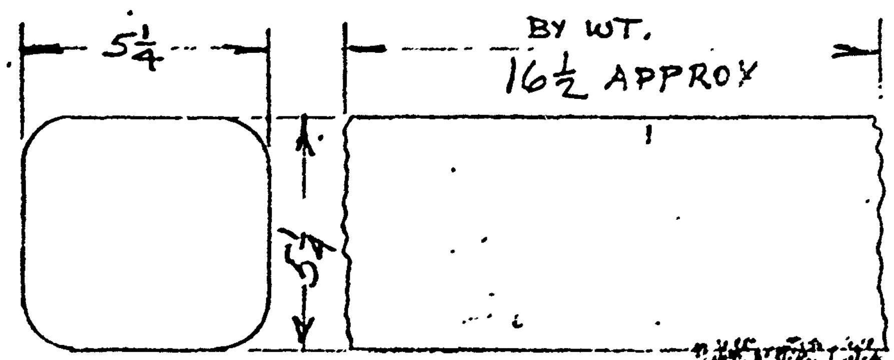


HEAT SLUG 2300 DEGREES FAHRENHEIT

LET.	REVISIONS	DATE	BY		DWG. DATE	SHEET
					5-4-78	1 OF 1

CHAMBERLAIN Corporation NEW BEDFORD DIV.	HYDRAULIC DESCALING CABINET	BODY, XM804, 155MM SHELL	
	ACCOUNT NO.	DRAWING NO. J8152	OPERATION NO. 30

MAT'L-STEEL BILLET

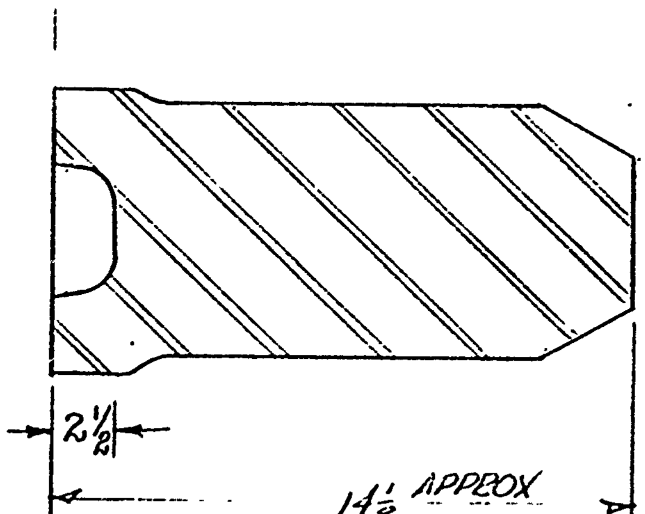


REMOVE SCALE

LET.	REVISIONS	DATE	BY.					DWG. DATE	SHEET
								5-4-78	1 OF 1

CHAMBERLAIN Manufacturing Corporation NEW BEDFORD DIV.	TYPE OF MACHINE CABBAGING PRESS 600 TON VERSION	JOB BODY XM804, 155 MM SHELL	
	~~ACCOUNT NO.~~ MAT'L:- STEEL BILLET	DRAWING NO. J8152	OPERATION NO. 35

T-4 CABBAGE DIES REF. R.R.D. 116030-1
T-116 PUNCH DIE HOLDER
T-129 DIE REMOVING FIXTURE
T-132 FORGING TONGS
T-133 FLAT FACE TONGS
T-131 GAS TORCH STAND
T-133 FORGE SHOP BLOW PIPES



ENTER CABBAGE DIE AT 2100° F.

— CABBAGE —

LET.	REVISIONS	DATE	BY					DWG. DATE 5-4-78 JUE R.	SHEET 1 OF 1

CHAMBERLAIN Manufacturing Corporation NEW BEDFORD DIV.	TYPE OF MACHINE TRANSFER MANIPULATOR	JOB BODY, XM804, 155MM. SHELL
	ACCOUNT NO.	DRAWING NO. J8152	OPERATION NO. 37

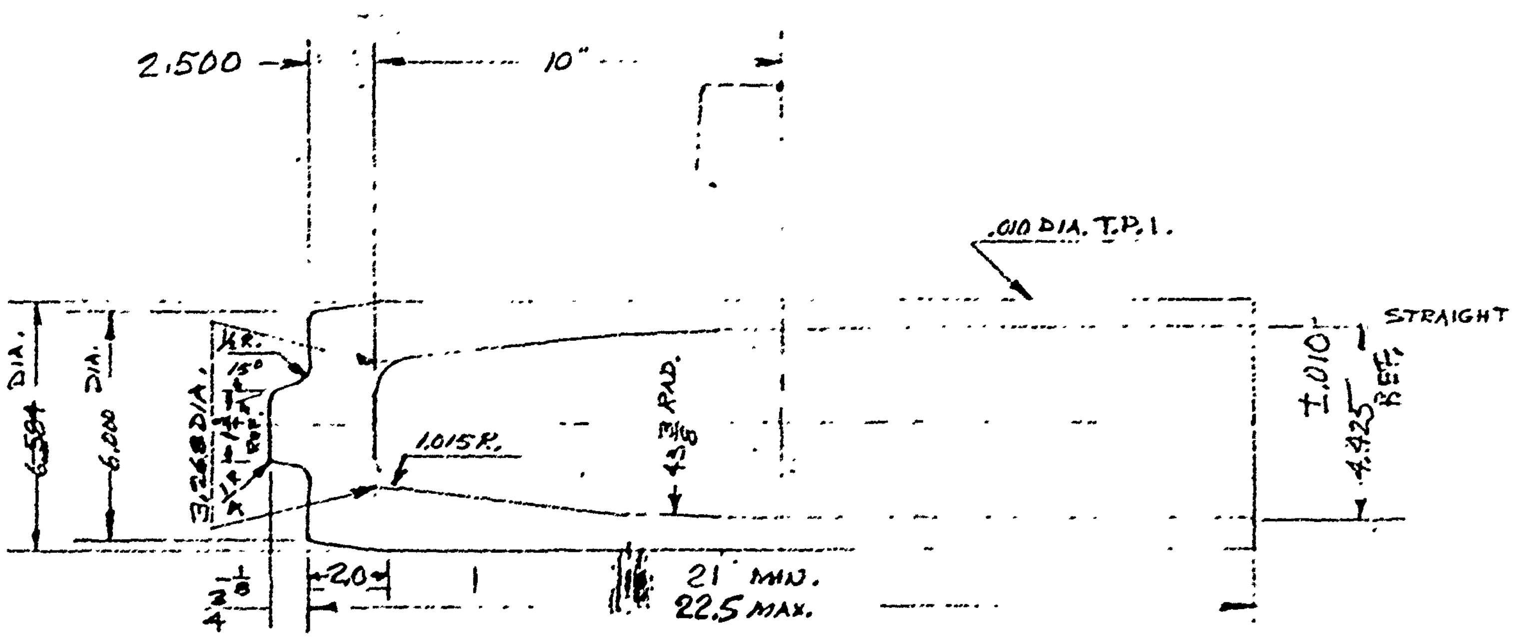
MAT'L - STEEL FORGING

TRANSFER FORGING FROM CABBAGE TO PIERCE PRESS

LET.	REVISIONS	DATE	BY				DWG. DATE	SHEET
							5-4-78	1 OF 1

CHAMBERLAIN Manufacturing Corporation, New Bedford Div.	TYPE OF MACHINE: PIERCING PRESS	JOB: BODY; XM804 155MM, SHELL	
	ACCOUNT NO.: 600 TON VERSON	DRAWING NO.: J8152	OPERATION NO.: 40

MAT'L - ST'L FORGING

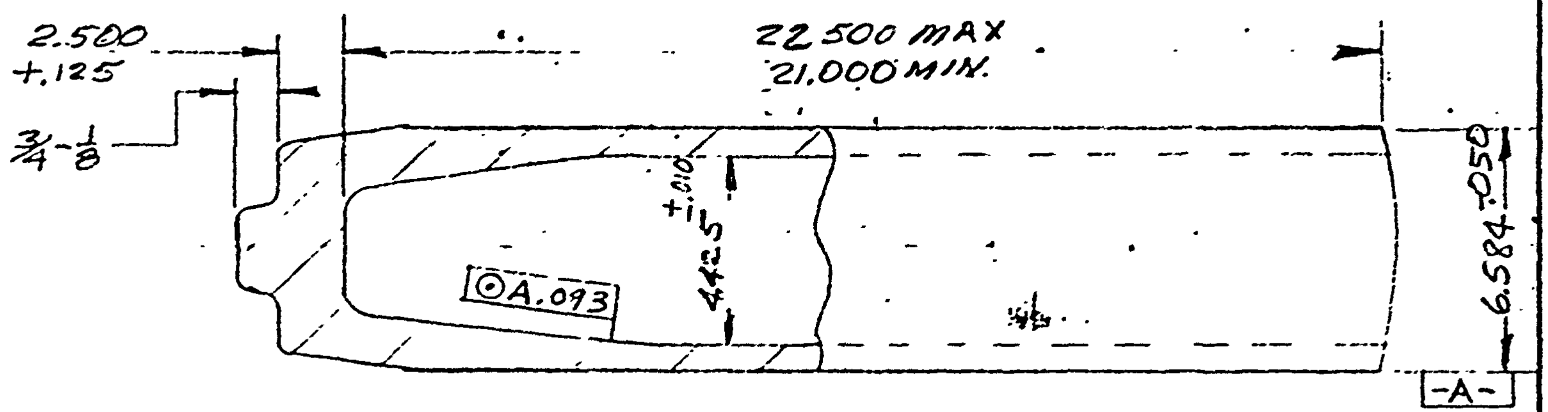


ENTER PIERCE DIE AT 1950°-2000°F.

PIERCE

LET.	REVISIONS	DATE	BY				DWG. DATE	SHEET
							5-4-78	1 OF 1

CHAMBERLAIN Manufacturing Corporation NEW BEDFORD DIV.	TYPE OF MACHINE INSP. STATION	JOB BODY, XM804 155MM, SHELL	
	ACCOUNT NO.	DRAWING NO. J8152	OPERATION NO. 53



DIM. FOR 1500° @ .0095 EXP./IN.

INSPECT HOT

LET.	REVISIONS	DATE	BY				DWG. DATE	SHEET
							5-4-78	1 OF 1

CHAMBERLAIN Manufacturing Corporation NEW BEDFORD DIV.	TYPE OF MACHINE TRANSFER BUGGY	JOB BODY, XM 804 155 MM SHELL	
	ACCOUNT NO.	DRAWING NO. J8152	OPERATION NO. 54

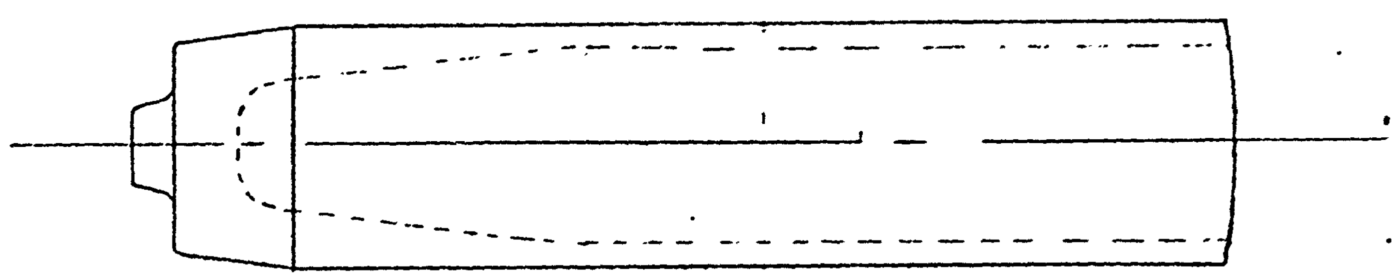
MAT'L - ST'L FORGING

TRANSFER TO COOLOUT

PRESS LINE & FURNACE RELIEF MAN

LET.	REVISIONS	DATE	BY	DWG. DATE	SHEET
				5-4-78	1 OF 1

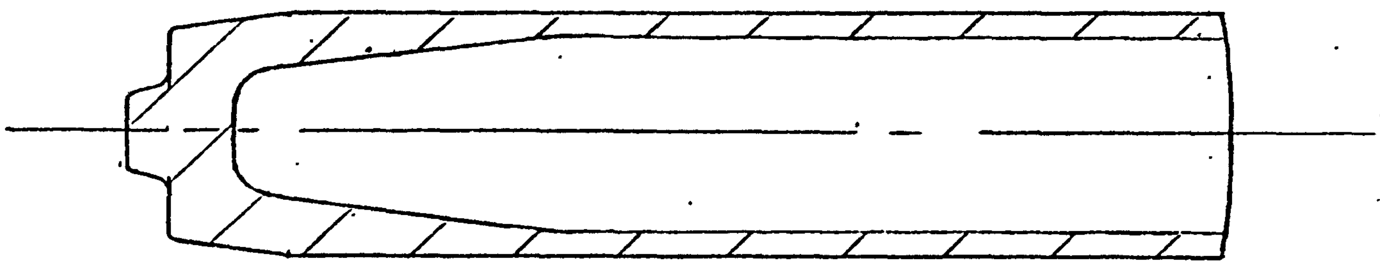
CHAMBERLAIN Manufacturing Corporation NEW BEDFORD DIV.	TYPE OF MACHINE COOLING CHAMBER	JOB BODY, XM804 155MM, SHELL	
	~~ACCOUNT NO.~~ LEE WILSON	DRAWING NO. J8152	OPERATION NO. 55



RETARD COOLING

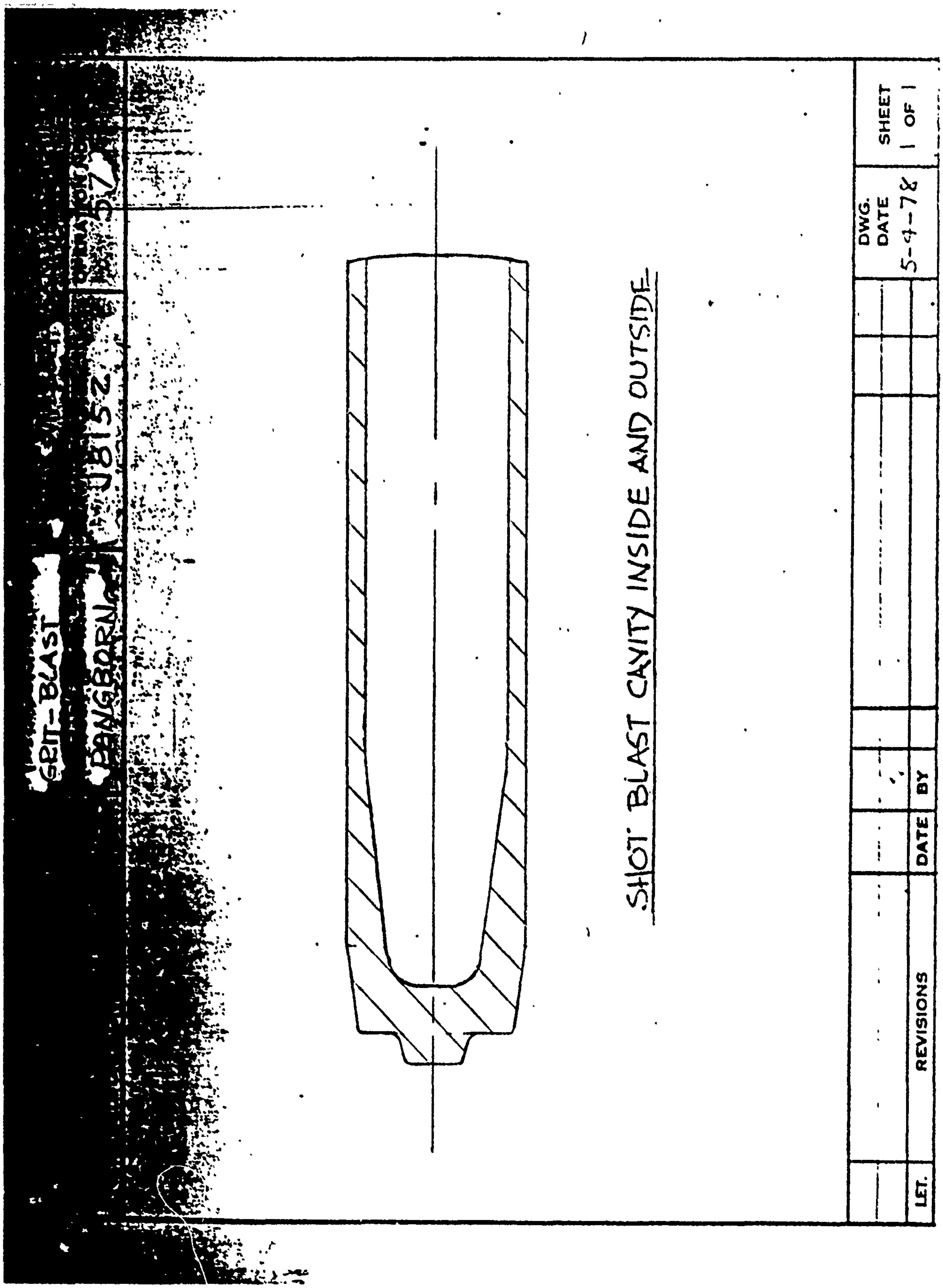
LET.	REVISIONS	DATE	BY	DWG. DATE	SHEET
				5-4-78	1 OF 1

CHAMBERLAIN Manufacturing Corporation NEW BEDFORD DIV.	TYPE OF MACHINE LEEDS & NORTHRUP FURNACE	JOB BODY, XM804 155MM, SHELL	
	~~ACCOUNT NO.~~	DRAWING NO. J8152	OPERATION NO. 56

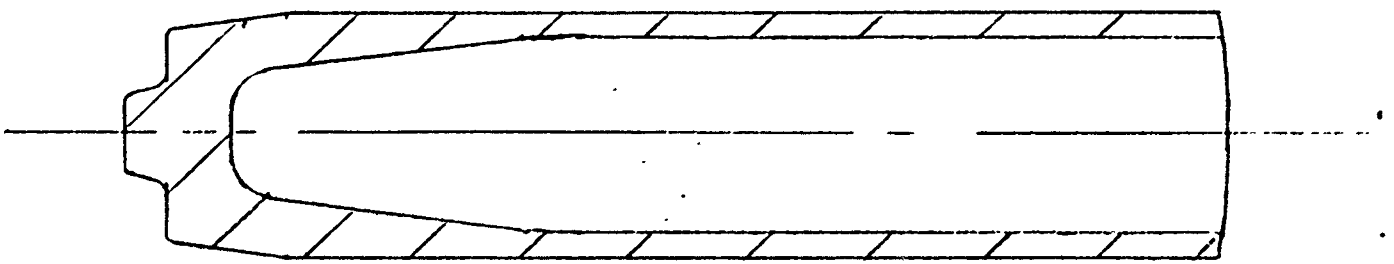


STRESS RELIEF 1250° FOR 2HRS

LET.	REVISIONS	DATE	BY	DWG. DATE	SHEET
				5-4-78	1 OF 1


GRIT-BLAST
PANGBORN
U8152
SHOT BLAST CAVITY INSIDE AND OUTSIDE
REVISIONS
LET.
DATE
BY
DWG. DATE
5-4-78
SHEET
1 OF 1

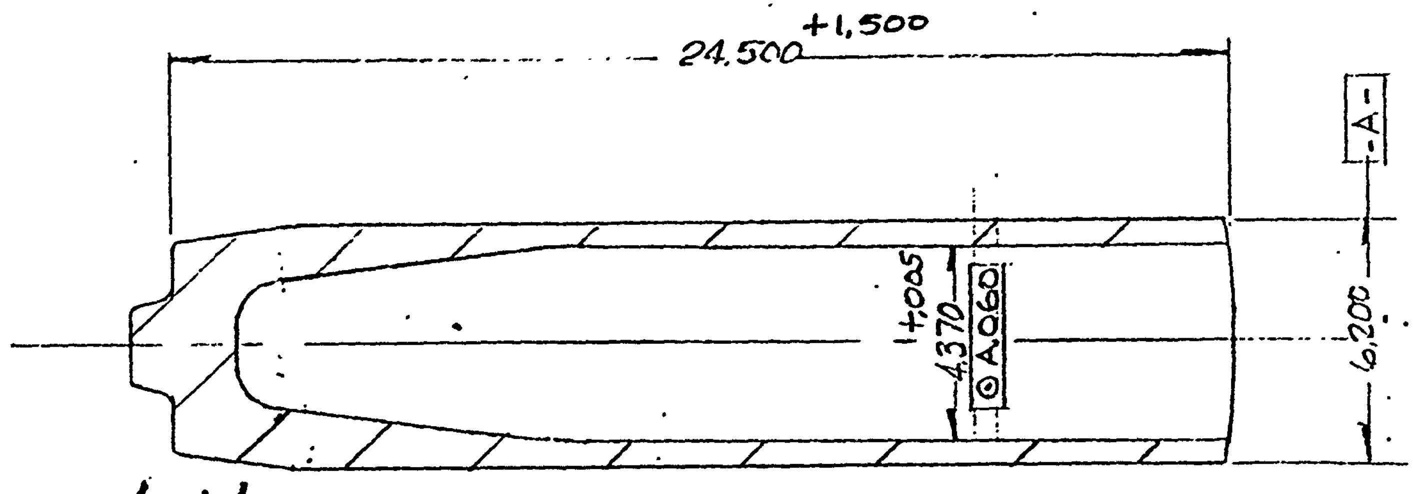
CHAMBERLAIN Manufacturing Corporation NEW BEDFORD DIV.	TYPE OF MACHINE BAKER UNIT	JOB BODY, XM804 155MM, SHELL	
	~~ACCOUNT NO.~~	DRAWING NO. J8152	OPERATION NO. 58



PHOSPHAT. LUBE COAT COMPLETE

LET.	REVISIONS	DATE	BY					DWG. DATE	SHEET
								5-4-78	1 OF 1

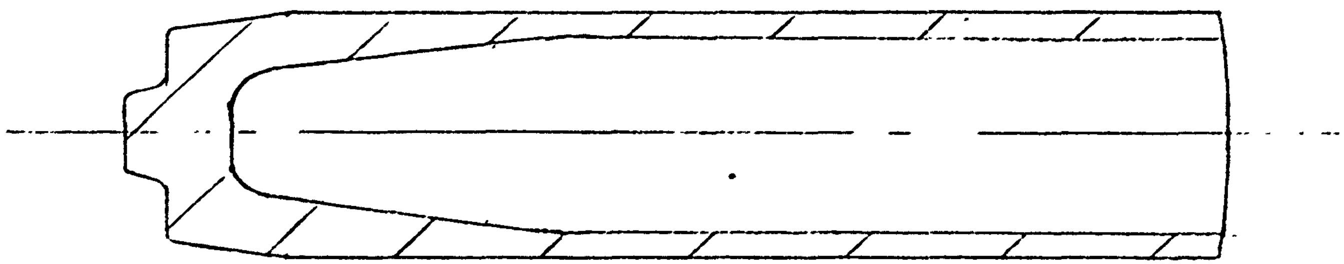
CHAMBERLAIN Manufacturing Corporation, New Bedford Div.	TYPE OF MACHINE: VERSON 600 TON HYD. PRESS	JOB: BODY, XM804 155MM, SHELL	
	~~ACCOUNT NO.~~	DRAWING NO.: J8152	OPERATION NO.: 59



COLD DRAW O.D. AND I.D.

LET.	REVISIONS	DATE	BY				DWG. DATE	SHEET
							5-4-78	1 OF 1

CHAMBERLAIN MANUFACTURING Corporation NEW BEDFORD DIV.	TYPE OF MACHINE LEEDS & NOTHRUP	JOB BODY, XM804 155MM, SHELL	
	~~ACCOUNT NO.~~	DRAWING NO. J8152	OPERATION NO. 60

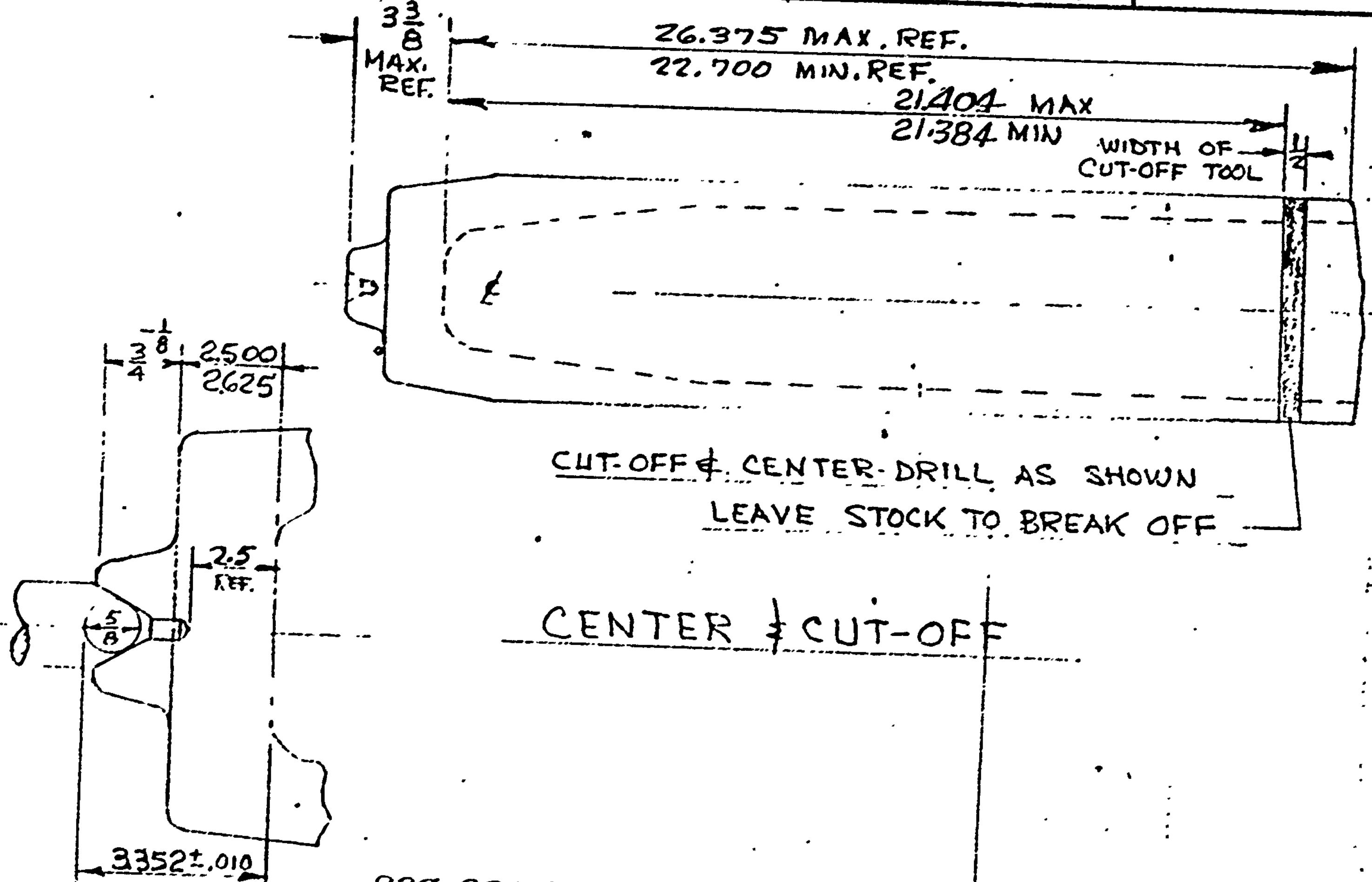


STRESS RELIEF 750°–1 HR.

LET.	REVISIONS	DATE	BY	DWG. DATE	SHEET
				5-4-78	1 OF 1

CHAMBERLAIN Manufacturing Corporation
NEW BEDFORD DIV.

TYPE OF MACHINE: AUTO. LATHE MOD. 8AX 36	JOB: BODY, XM804, 155MM SHELL		
SUNDSTRAND	DRAWING NO. J8152	OPERATION NO. 75	

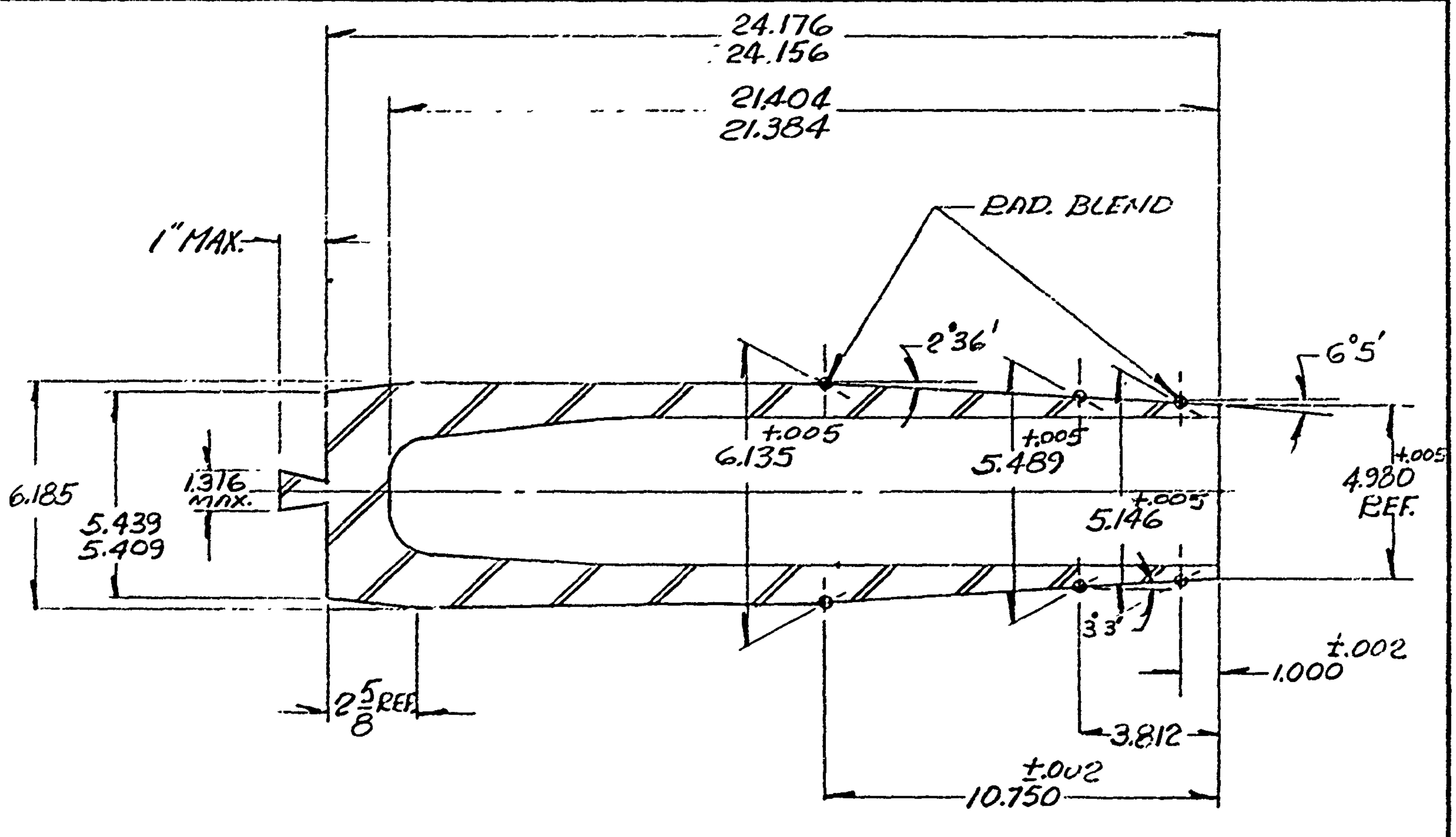


CENTER & CUT-OFF

927-G20 A FLUSH PIN 21.492±.020

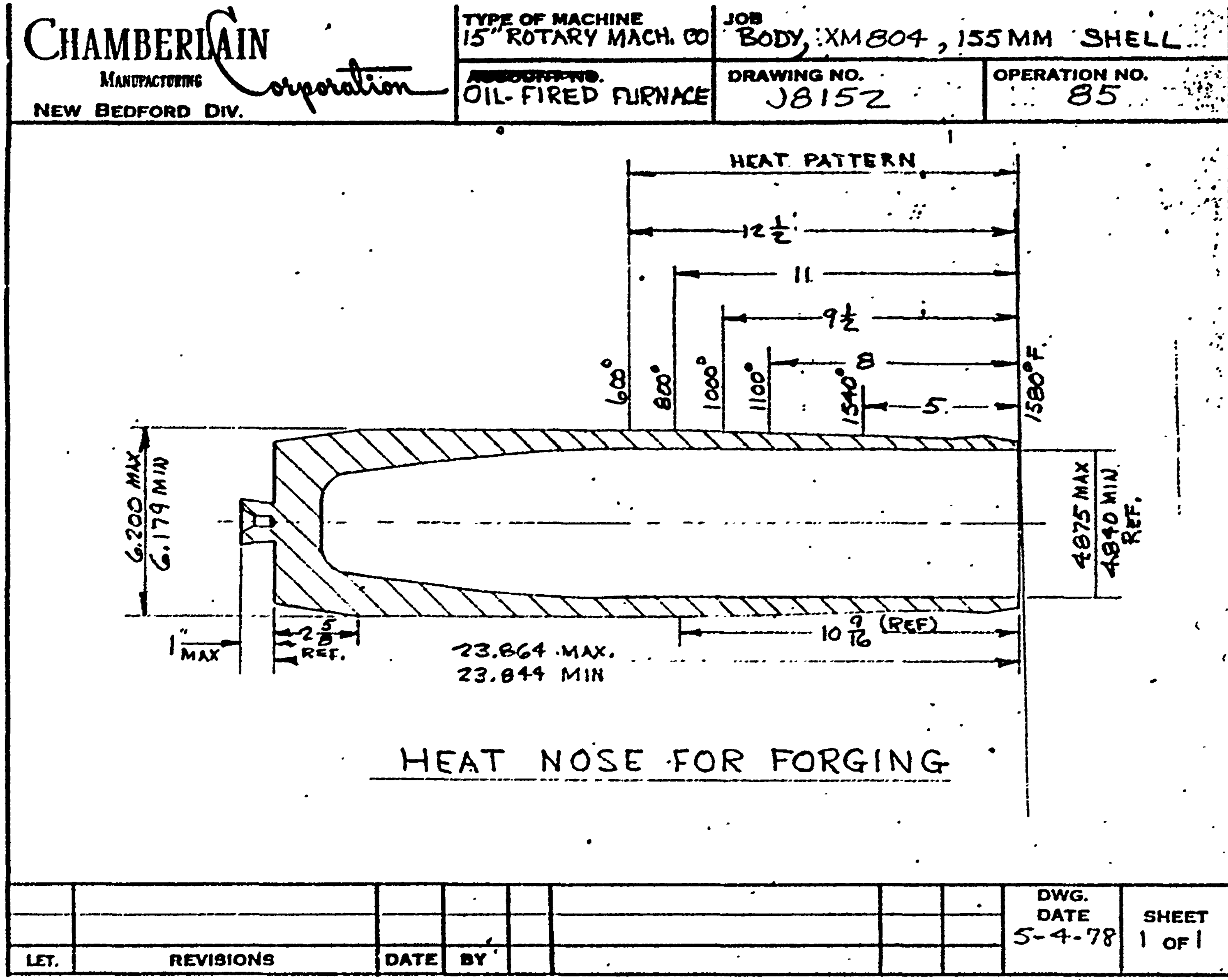
LET.	REVISIONS	DATE	BY	DWG. DATE	SHEET
				5-4-78	1 OF 1

CHAMBERLAIN Manufacturing Corporation NEW BEDFORD DIV.	TYPE OF MACHINE S.F.M. MOD. R-14	JOB XM804 BODY 155 MM SHELL	
	ACCOUNT NO.	DRAWING NO. J8152	OPERATION NO. 80

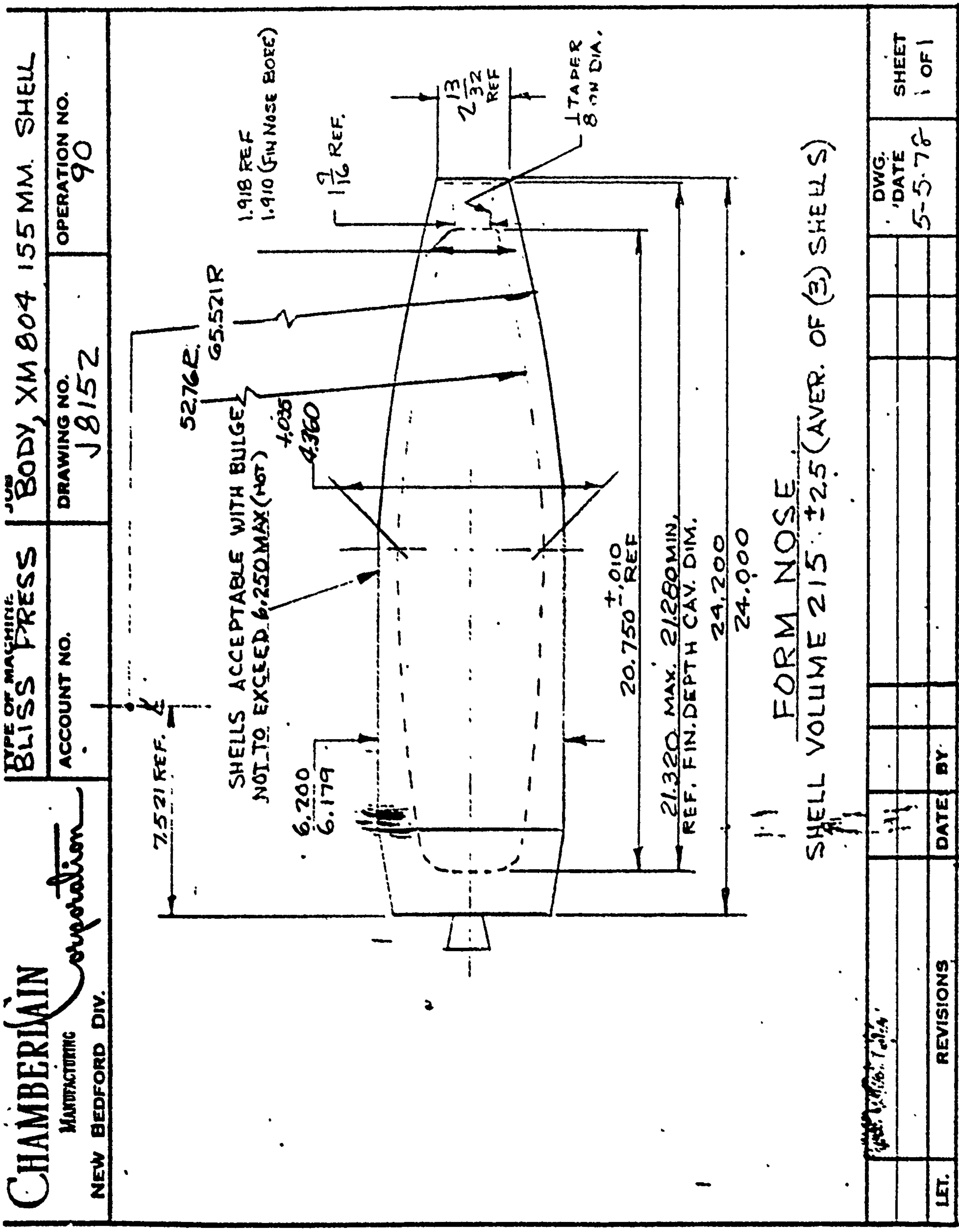


ROUGH TURN CONTOUR

LET.	REVISIONS	DATE	BY				DWG. DATE 7/28/78	SHEET 1 OF 1

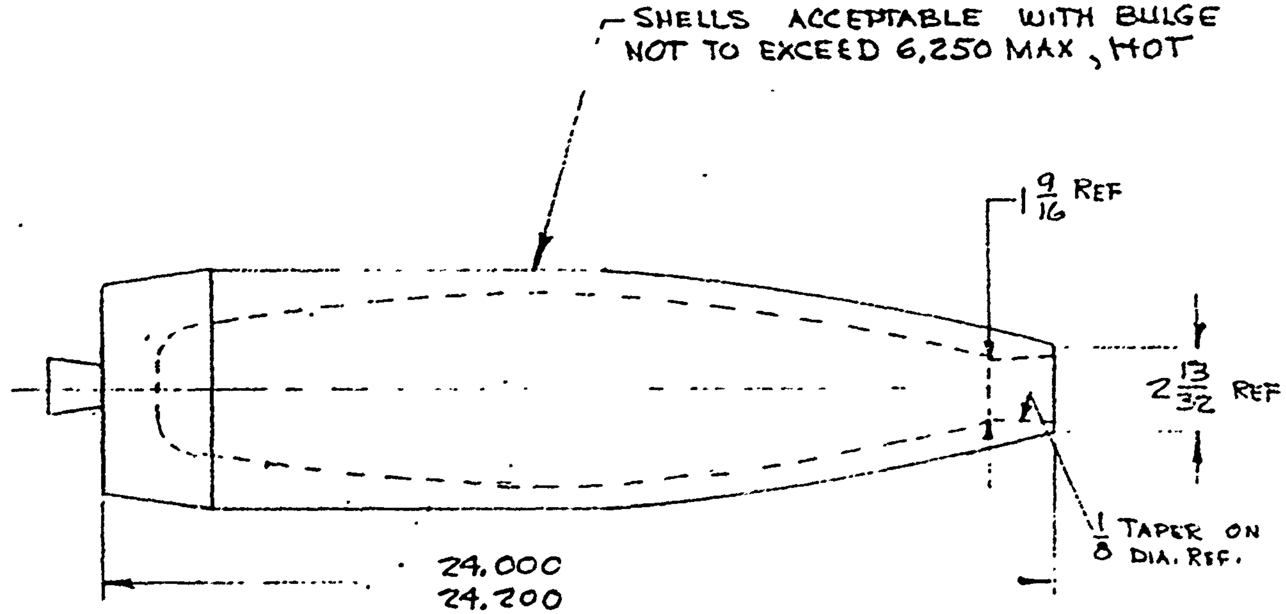


CHAMBERLAIN Manufacturing Corporation
NEW BEDFORD DIV.
TYPE OF MACHINE
15" ROTARY MACH. CO
JOB
BODY, XM804, 155MM SHELL
OIL-FIRED FURNACE
DRAWING NO.
J8152
OPERATION NO.
85
HEAT PATTERN
12 1/2
11
9 1/2
8
5
680°
800°
1000°
1100°
1540°
1580°F
6.200 MAX
6.179 MIN
4875 MAX
4840 MIN
REF.
1" MAX
2 5/8 REF.
10 9/16 (REF)
23.864 MAX.
23.844 MIN
HEAT NOSE FOR FORGING
LET.
REVISIONS
DATE
BY
DWG. DATE
5-4-78
SHEET
1 OF 1



CHAMBERLAIN
Manufacturing Corporation
New Bedford Div.
TYPE OF MACHINE BLISS PRESS
ACCOUNT NO.
JOB BODY, XM 804 155 MM. SHELL
DRAWING NO. J8152
OPERATION NO. 90
1.918 REF
1.910 (FIN NOSE BORE)
1 9/16 REF.
2 13/32 REF
⊥ TAPER 8 ON DIA.
65.521 R
52.76 R
4.035
4.360
SHELLS ACCEPTABLE WITH BULGE NOT TO EXCEED 6.250 MAX (HOT)
7.521 REF.
6.200
6.179
20.750 +.010 REF
21.320 MAX. 21.280 MIN.
REF. FIN. DEPTH CAV. DIM.
24.200
24.000
FORM NOSE
SHELL VOLUME 215 ± 2.5 (AVER. OF (3) SHELLS)
DWG. DATE 5-5-76
SHEET 1 OF 1
LET.
REVISIONS
DATE
BY

CHAMBERLAIN MANUFACTURING Corporation NEW BEDFORD DIV.	TYPE OF MACHINE INSPECT. STA.	JOB BODY, XM804, 155MM SHELL	
	ACCOUNT NO.	DRAWING NO. J8152	OPERATION NO. 93



INSPECTION STATION

CHECK NOSE CONTOUR, VOLUME, CONCENTRICITY & WALL THICKNESS

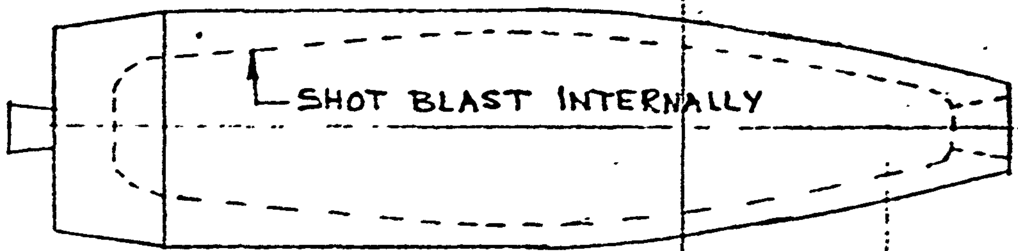
LET.	REVISIONS	DATE	BY					DWG. DATE	SHEET
								5-5-78	1 OF 1

CHAMBERLAIN Manufacturing Corporation NEW BEDFORD DIV.	TYPE OF MACHINE	JOB BODY, XM 804, 155 MM	SHELL
	ACCOUNT NO.	DRAWING NO. J8152	OPERATION NO. 103

TRANSFER TO SHOT BLAST

LET.	REVISIONS	DATE	BY				DWG. DATE	SHEET
							5-5-78	1 OF 1

CHAMBERLAIN Manufacturing Corporation NEW BEDFORD DIV.	TYPE OF MACHINE PANGBORN	JOB BODY, XM804 ; 155MM SHELL	
	GRIT - BLAST	DRAWING NO. J8152	OPERATION NO. 105

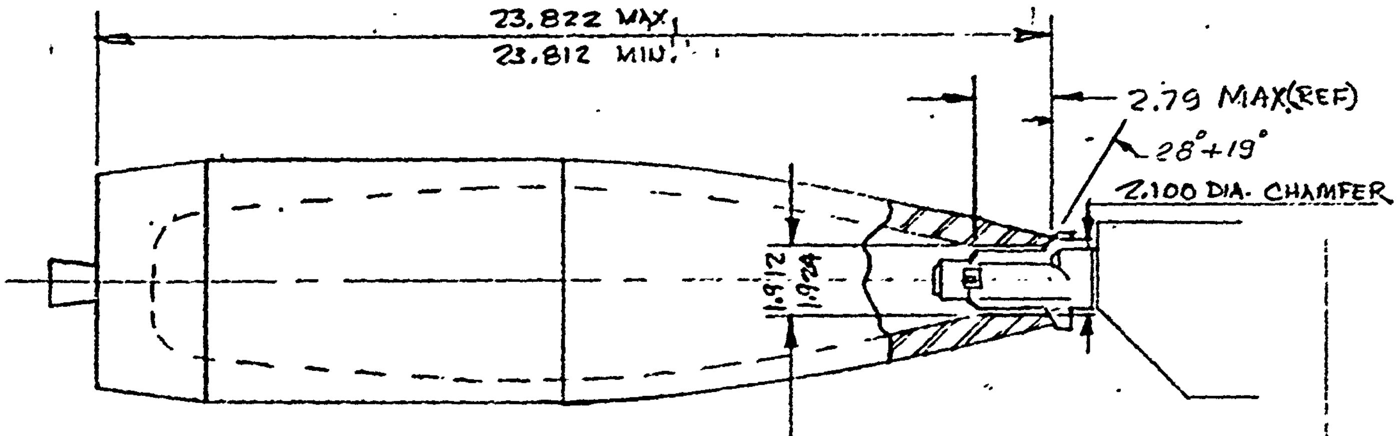


SHOT BLAST INTERNALLY

LET.	REVISIONS	DATE	BY					DWG. DATE	SHEET
								5-5-78	1 OF 1

CHAMBERLAIN Manufacturing Corporation NEW BEDFORD DIV.	TYPE OF MACHINE 5x46 AUTO LATHE	JOB BODY, XM804, 155MM SHELL	
	~~ACCOUNT NO.~~ SENECA. FALLS	DRAWING NO. J8152	OPERATION NO. 120

927-G45A LENGTH GAGE 23.822-.010
G46 CHAMFER GAGE 2.100+.020
G319 D.E. CYL. PLUG 1.912 +.012



BORE; CHAMFER; FINISH; FACE

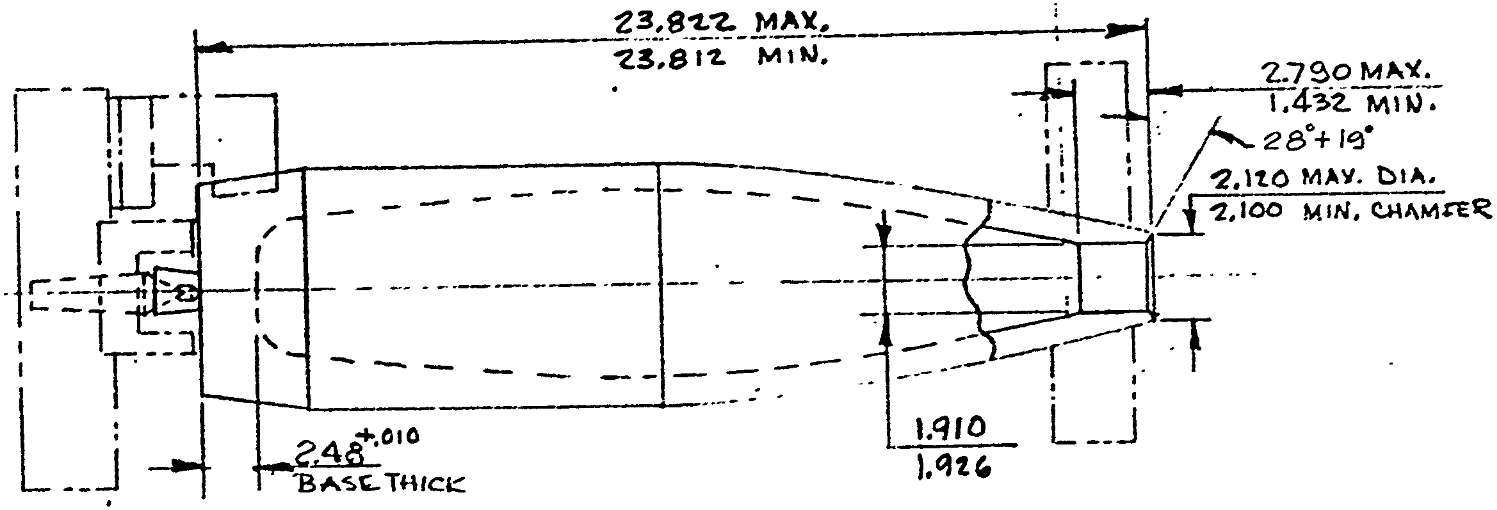
LET.	REVISIONS	DATE	BY				DWG. DATE	SHEET
							5-5-78	1 OF 1

CHAMBERLAIN Manufacturing Corporation .NEW BEDFORD DIV.	TYPE OF MACHINE INSPECT. STA.	JOB BODY, XM804 155MM SHELL
	ACCOUNT NO.	DRAWING NO. J8152 — OPERATION NO. 123

927-G45A LENGTH GAGE 23.822 -.010

G46 CHAMFERGAGE 2.100 +.020

G320 D.E. CYL. PLUG 1.910 +.016



INSPECTION, BORE, CHAMFER, FINISH FACE

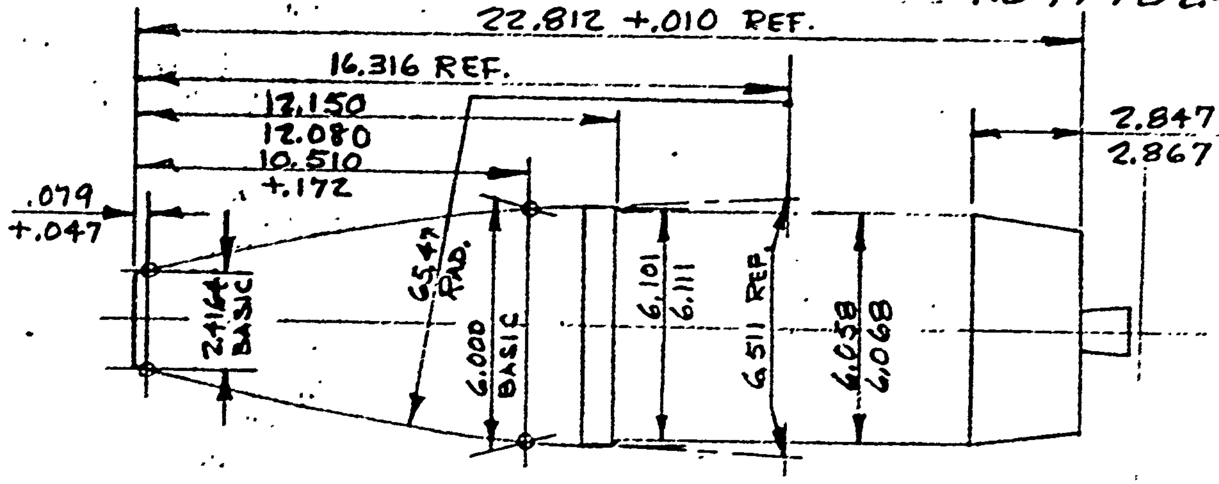
INSERT NOSE CAP AFTER INSPECTION

LET.	REVISIONS	DATE	BY				DWG. DATE	SHEET
							5-5-78	1 OF 1

CHAMBERLAIN Manufacturing Corporation, New Bedford Div.	TYPE OF MACHINE: LO-SWING R-14	JOB: BODY, XM804, 155MM SHELL	
	ACCOUNT NO.	DRAWING NO. J8152	OPERATION NO. 125

927-G51 DIAL SNAP 6.101-6.111
G52 " " 6.058-6.068
G55 TEMPLATE LENGHT 2.847-.020
G78A " " 12.08 +.070

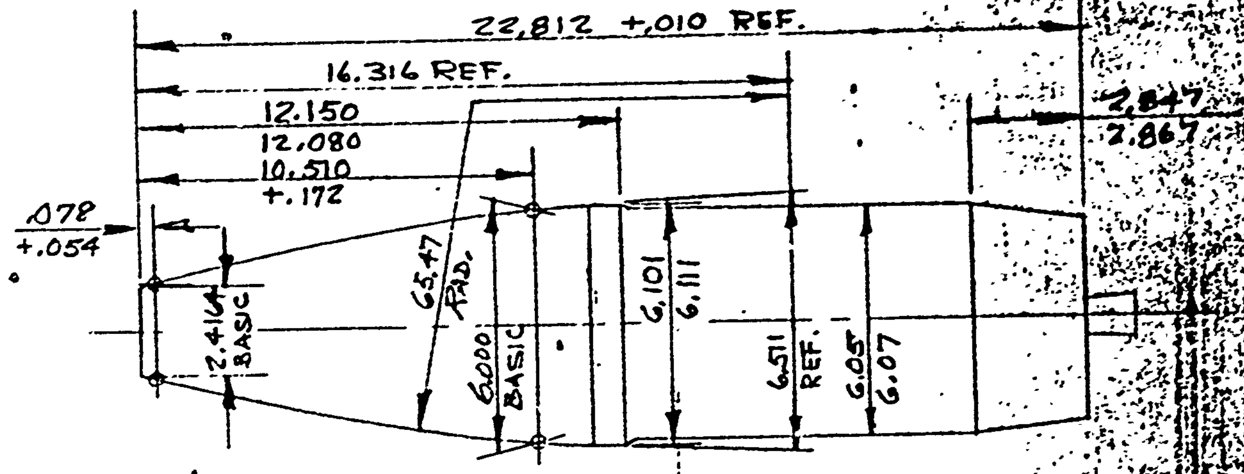
G300 FLUSHPIN 10.510 +.172 TO 6.000 BSC.
G301A TEMPLATE SNAP .079 +.047 TO 2.4164 BSC



FINISH TURN

LET.	REVISIONS	DATE	BY	DWG. DATE	SHEET
				5-5-78	1 OF 1

CHAMBERLAIN Manufacturing Corporation, New Bedford Div.	TYPE OF MACHINE: INSPECTION	JOB: BODY, XM804, 155 MM SHELL
	ACCOUNT NO.	DRAWING NO. 18152 / OPERATION NO. 1-29

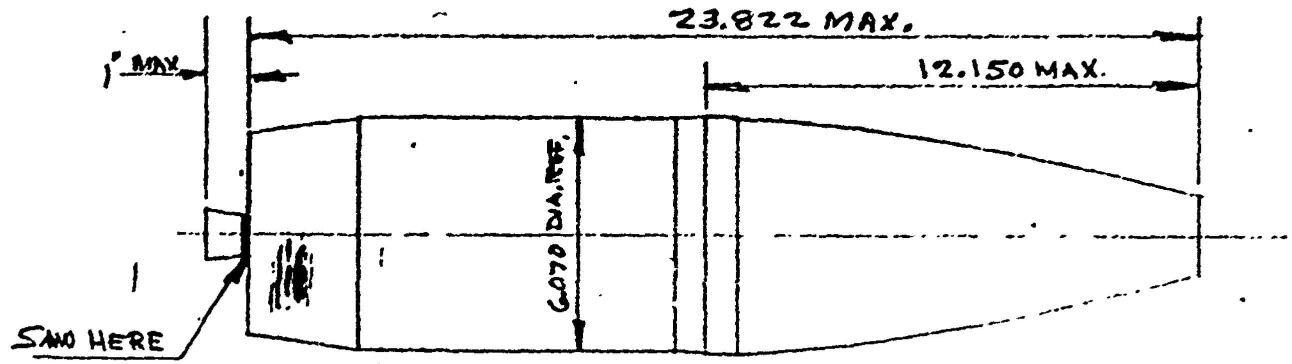


FINISH TURN INSPECTION

927- G51 DIAL SNAP 6.101-6.111
G53 " " 6.05-6.07
G55 TEMPLATE LENGHT 2.847/2.867
G78A " " 12.08+.07
G300 FLUSH PIN 10.510+.172 TO 6.00 BSC.
G301 TEMPLATE SNAP .073+.054 TO 2.4164 BSC.

LET.	REVISIONS	DATE	BY		DWG. DATE	SHEET

CHAMBERLAIN Manufacturing Corporation, New Bedford Div.	TYPE OF MACHINE: RACINE SAW	JOB: BODY, XM804, 155MM. SHELL	
	ACCOUNT NO.	DRAWING NO. 18152	OPERATION NO. 130

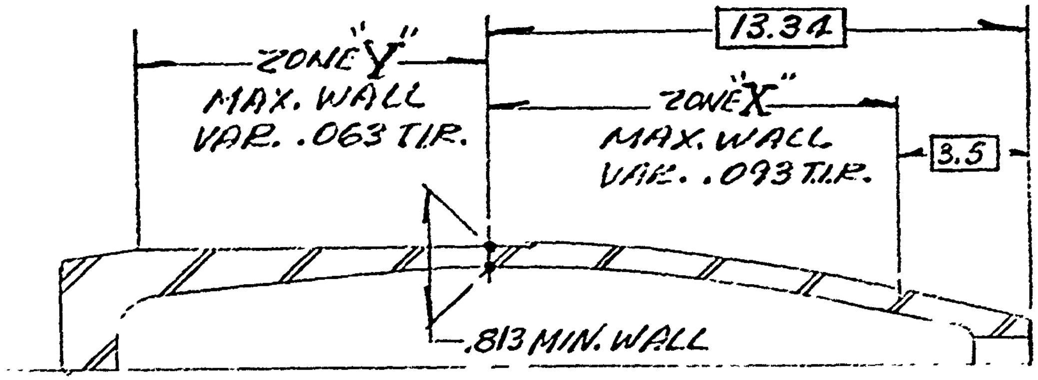


REMOVE CENTER BOSS

VISUALLY CHECK THAT NOSE CAP IS IN PLACE

LET.	REVISIONS	DATE	BY	DWG. DATE	SHEET
				5.5.78	1 OF 1

CHAMBERLAIN Manufacturing Corporation NEW BEDFORD DIV.	TYPE OF MACHINE	JOB BODY, XM804, 155MM SHELL	
	ACCOUNT NO.	DRAWING NO. J8152	OPERATION NO. OP. 131



REMOVE NOSE CAP PRIOR TO INSPECTING WALL VAR. & THICK. INSERT NOSE CAP AFTER INSPECTION.

INSPECTION AND WEIGH (VISUAL)
APPLIES TO FORGINGS WITHOUT TEAT ONLY

G113	WEIGHT SCALE	94.0	91.4
"	MAX. WALL VARIATION CALIPER	.063	
G-75	MIN. WALL THICKNESS	—	.8135
GAGE	DESCRIPTION	SIZE MAX.	MIN.

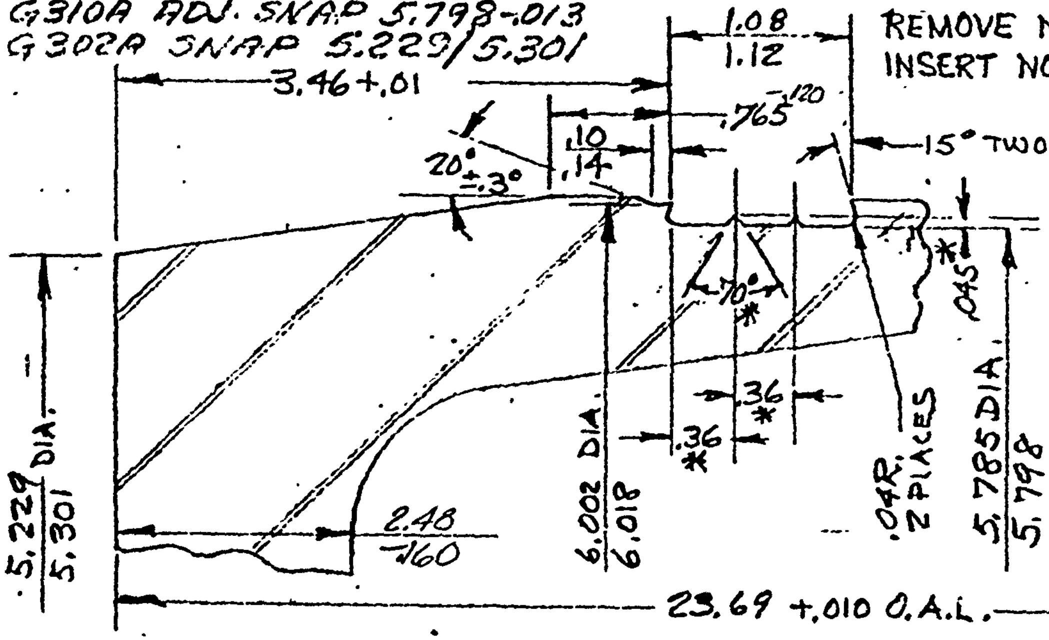
LET.	REVISIONS	DATE	BY					DWG. DATE	SHEET
								5-12-78	1 OF 1

CHAMBERLAIN Corporation, Manufacturing, New Bedford Div.	TYPE OF MACHINE: LO-SWING AR	JOB: BODY XM804, 155 MM SHELL	
	ACCOUNT NO.	DRAWING NO. 18152	OPERATION NO. 135

927-G63A LENGHT 23.69+.010
G64A TEMPLATE 3.46+.010
G65 WIDTH .10+.04
G66 WIDTH 1.08+.04
G190 TEMPLATE .765-.120
G310A ADJ. SNAP 5.798-.013
G302A SNAP 5.229/5.301

G311A ADJ. SNAP 6.08-.016
G328 TEMPLATE 20°±3° (SETUP)
G329 " 15°±2° (SETUP)
G331 " 15°±2° (SETUP)
G . BASE THICKNESS 2.48-.160

REMOVE NOSE CAP PRIOR TO MACHING
INSERT NOSE CAP AFTER MACHING



TOLERANCE UNLESS SPECIFIED:
DECIMAL = ±.010
ANGLE = ±2°
* = TOOL CONTROL DIM.

LET.	REVISIONS	DATE	BY	DWG. DATE	SHEET
				5-5-78	1 OF 1

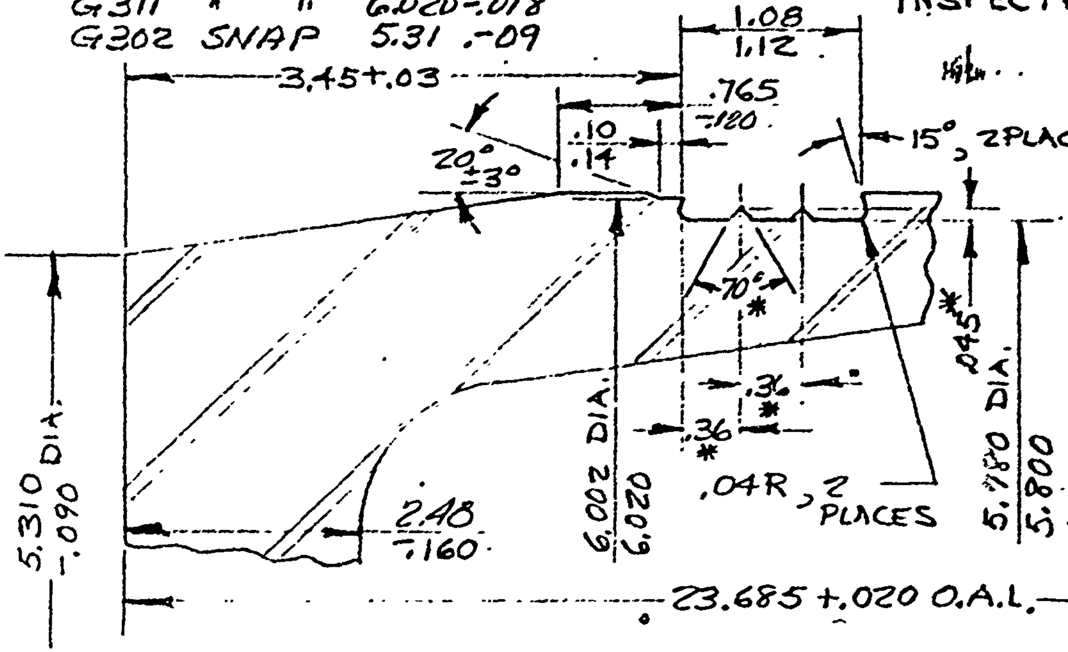
CHAMBERLAIN Manufacturing Corporation, New Bedford Div.	TYPE OF MACHINE: INSPECTION	JOB: BODY, XM804, 155 MM SHELL	
	ACCOUNT NO.	DRAWING NO. J8152	OPERATION NO. 138

927-G63 LENGHT 23.685 +.020
G64B TEMPLATE 3.45 +.030
G65 " .10 +.04
G66A " 1.08 +.04
G190 " .765 -.120
G310 ADJ. SNAP 5.80 -.02
G311 " " 6.020 -.018
G302 SNAP 5.31 -.09

G

BASE THICKNESS 2.48 -.16

REMOVE NOSE CAP PRIOR TO INSPECTING LENGTH. INSERT CAP AFTER INSPECTION.

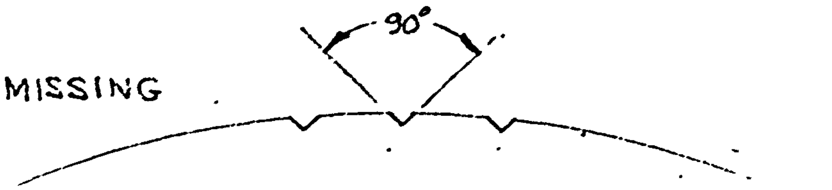


TOLERANCE UNLESS SPECIFIED:
DECIMAL = ±.010
ANGLES = ±2°
* = TOOL CONTROL DIM.

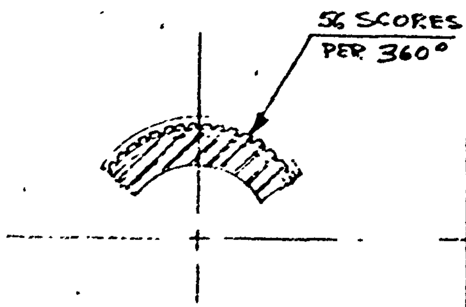
LET.	REVISIONS	DATE	BY	DWG. DATE	SHEET
				5-5-78	1 OF 1

CHAMBERLAIN Manufacturing Corporation NEW BEDFORD DIV.	TYPE OF MACHINE SCHMIDT	JOB BODY, XM804 155MM SHELL
	~~ACCOUNT NO.~~ KNURL MACH.	DRAWING NO. J8152 — OPERATION NO. 140

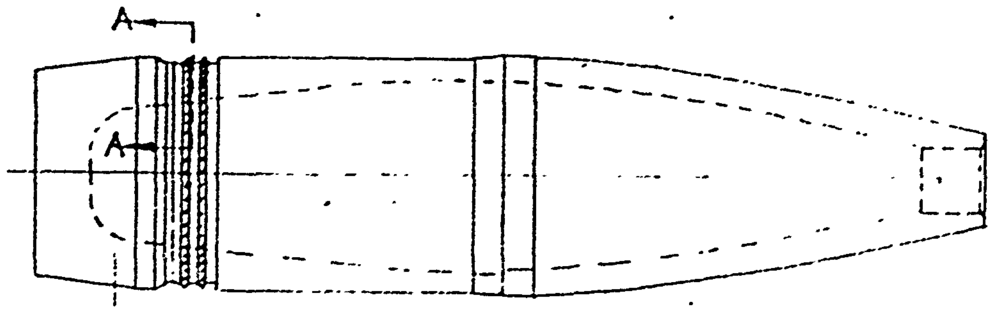
INSERT NOSE CAP IF ONE IS MISSING



SCALE ENLARGEMENT OF SCORES



PARTIAL SECTION A-A



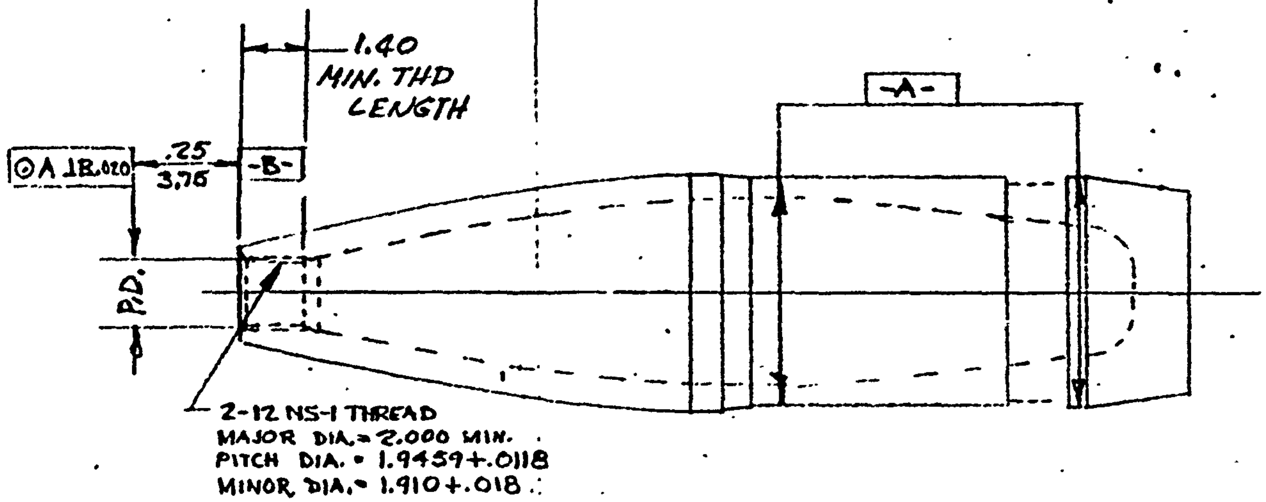
NOTE:
KNURLING ROLL MUST BE
SET TO SHOW TOOL MARKS
ON BAND SEAT.

KNURL BAND GROOVE

LET.	REVISIONS	DATE	BY	DWG. DATE	SHEET
				5-5-78	1 OF 1

CHAMBERLAIN Manufacturing Corporation NEW BEDFORD DIV.	TYPE OF MACHINE LANDIS #1½-R-L	JOB BODY, XM804, 155MM SHELL	
	THREADING MACH.	DRAWING NO. 18152	OPERATION NO. 145

REMOVE NOSE CAP PRIOR TO MACHINING
INSERT NOSE CAP AFTER MACHINING



927-G122 SETUP GAGE RING 2.00
G99 GO THREAD PLUG
G100 NO GO THREAD PLUG
G319 CYL. PLUG 1.910+.018

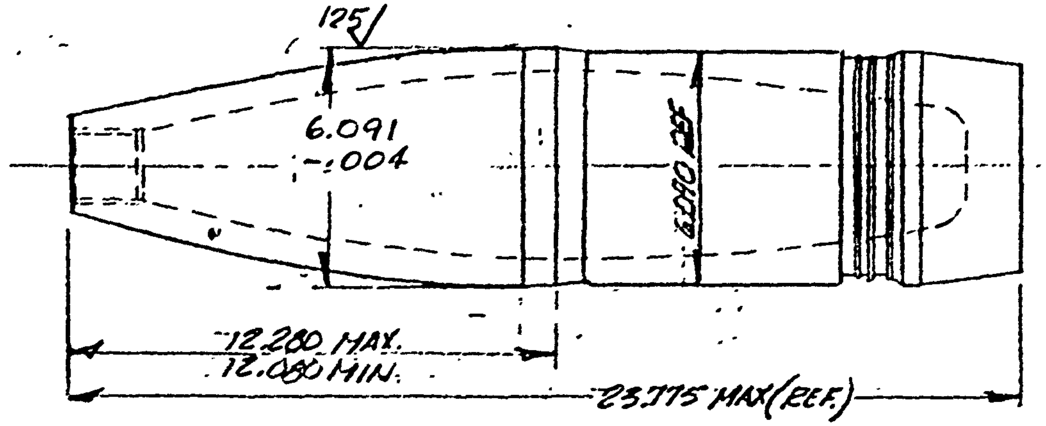
TAP THREAD IN NOSE

LET.	REVISIONS	DATE	BY	DWG. DATE	SHEET
				5-5-78	1 OF 1

CHAMBERLAIN Manufacturing Corporation NEW BEDFORD DIV.	TYPE OF MACHINE: CENTERLESS GRINDER CINN. #2	JOB BODY, XM804 ; 155MM.	
	ACCOUNT NO.	DRAWING NO. 1J8152	OPERATION NO. 150

T-76 = WORK REST
G-71 = 6.091 - 6.088 DIAL SNAP GAGE
G-78 = TEMP. POSITION BOUR. 12.280 - 12.080
T-119 = WHEEL BALANCING ARBOR.
927 - G77 DIAL SNAP 6.091 -.004
G78 TEMPLATE LENGHT 12.28 -.20

INSERT NOSE CAP IF ONE IS MISSING



FINISH GRIND BOURRELET

LET.	REVISIONS	DATE	BY	DWG. DATE	SHEET
				5-6-78 ISSUE R	1 OF 1

CHAMBERLAIN MANUFACTURING Corporation
NEW BEDFORD DIV.

TYPE OF MACHINE: INSP. STAT A
JOB: 155MM XM804
ACCOUNT NO.:
DRAWING NO.: J8152-1
OPERATION NO.: 153

DEFECT	GAGE NO	DEFECT	GAGE NO
CRITICAL		119	927 G312 BOAT TAIL AT BASIC (.020 FIM
1	SURFACE DEFECTS,, CRACK, ETC. VISUAL	120	927 G312 PERP REAR FACE (.050)
MAJOR		121	927-G312 WALL THKN VAR (.063 MAX
101	927 G310 ADJ SNAP (5.79 ±.01)	122	927-G312 WALL THKN VAR (.09 MAX)
102	927 G64B TEMPLATE (3.48-.03)	123	927 G312 WALL THKN MIN (.3135)
103	" " G66A TEMPLATE (1.08+.04)	124	927 G99 GO THRD & MET 1.39
104	" " G190 TEMPLATE (.765-.120)		MINOR
105	KNURL DEPTH VISUAL (.010 MAX	201	927-G78 TEMPLATE (12.28-.20)
106	SCORING OR KNURL MISSING (VISUAL	202	927-G46 SPEC. PLUG (2.11 ±.01
107	927 G107 LENGTH (23.80-.20	203	TOOL CONTROL
108	804- G96 FLUSH PIN (2.48-.16)	204	927-G302 TEMPLATE SNAP (5.31-.09
109	927-G77 DIAL SNAP (6.091-.004	205	927-G165 TEMPLATE (2.79
110	927-G53 DIAL SNAP (6.06 ±.01)	206	801-G9 I.D. (4.360 +.035) CHECKED IN FORGE RM.
111	927-G301 TEMPLATE SNAP (.073+.05)		
112	927 G300 DATUM FLUSH PIN 10.510 +.172	207	SURFACE FINISH AT BOURRELET (VISUAL)
113	927-G100 NOT GO THRD PLUG (2-12 MAX 1.9577	208	WORKMANSHIP, RADII, FINISH, FOREIGN MATERIAL, ETC (VISUAL)
114	927-G99 GO THRD PLUG (1.9459)		
115	927-G309 PLUG GAGE (1.928)		
116	927-G312 & 927-G312A (.030 FIM)		
117	927 G312 BOURRELET (.010 FIM)		
118	927-G312 OGIVE AT BASIC (.020 FIM		

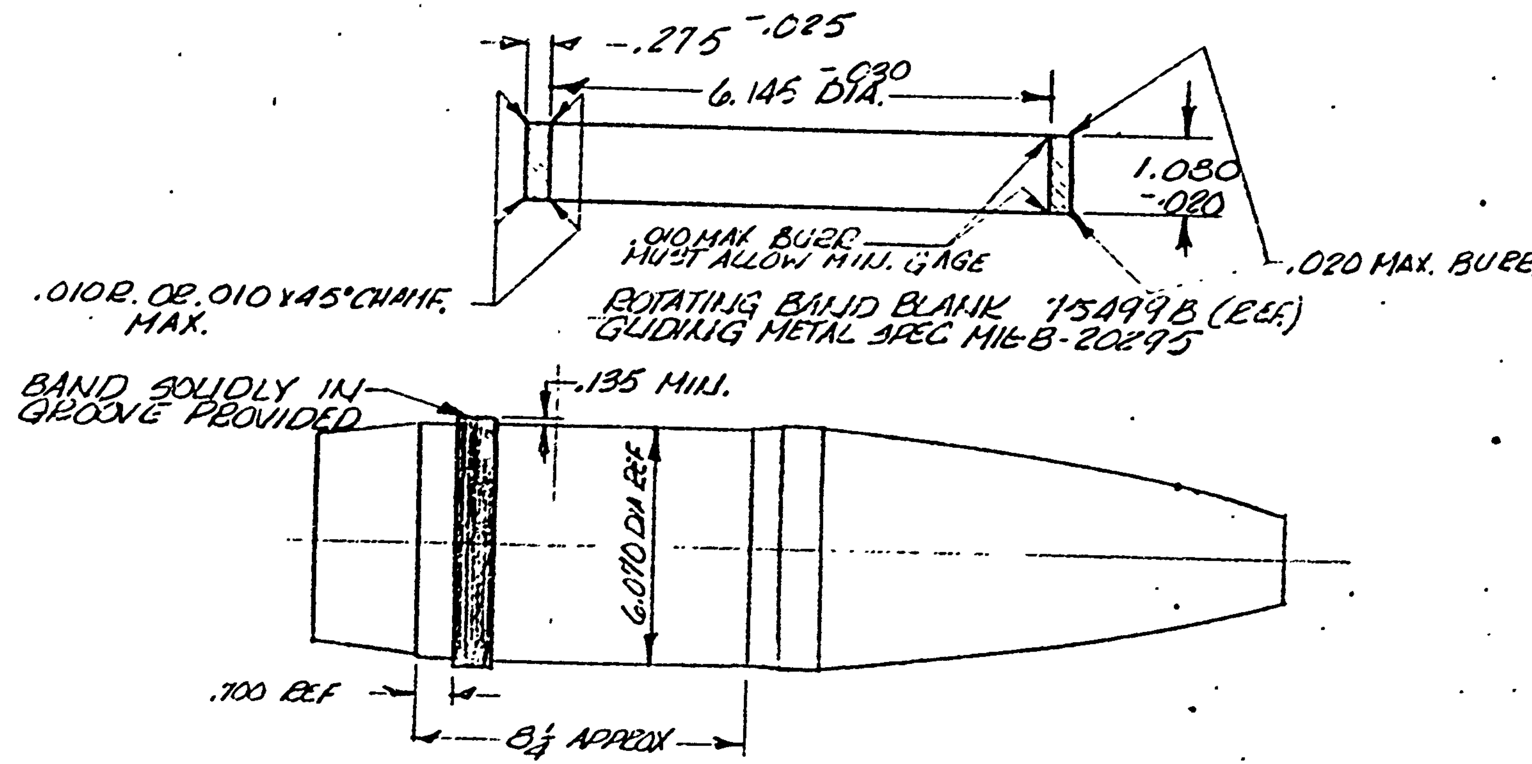
LET.	REVISIONS	DATE	BY	DWG. DATE	SHEET
				6-26-78	1 OF 1

CHAMBERLAIN Corporation
MANUFACTURING
NEW BEDFORD DIV.

TYPE OF MACHINE: WATSON STILLMAN BANDING PRESS	JOB: BODY, XM804, 155MM		
ACCOUNT NO.	DRAWING NO.: J8152	OPERATION NO.: 155	

T-79 BANDING SHOES

MATERIAL: STEEL FORGING



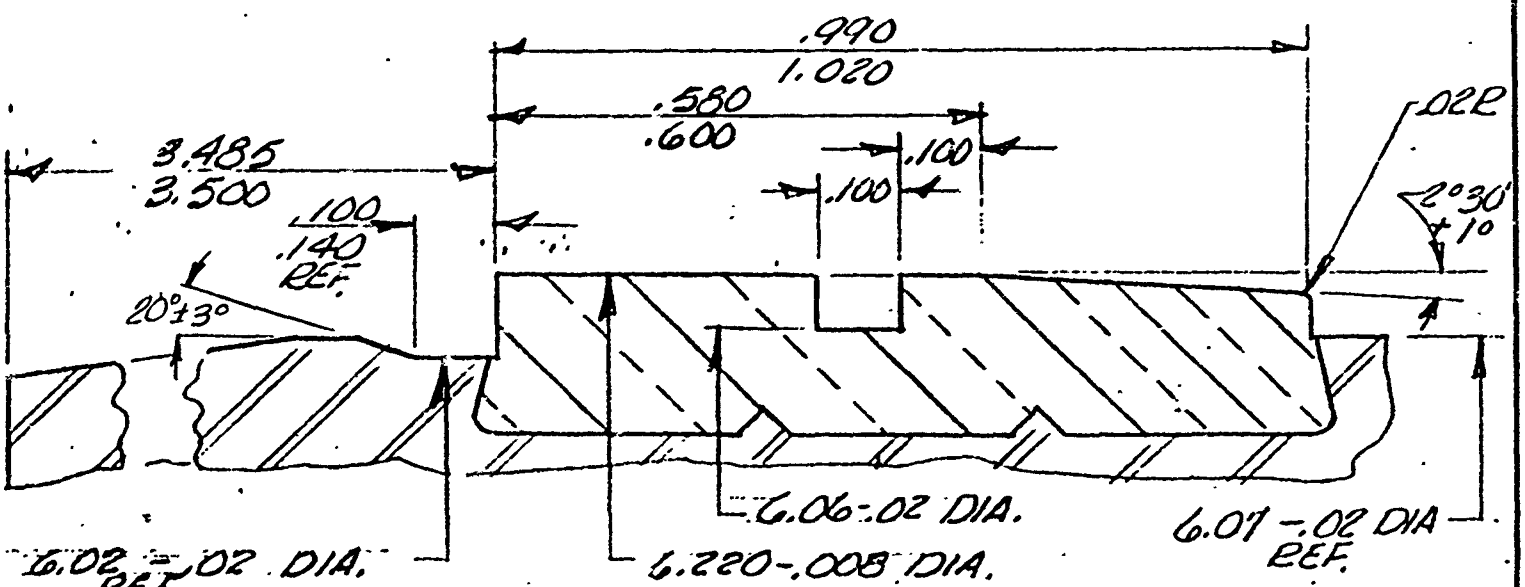
ASSEMBLE ROTATING BAND

LET.	REVISIONS	DATE	BY	DWG. DATE	SHEET
				5-5-78 SUE R	1 OF 1

CHAMBERLAIN Manufacturing Corporation, NEW BEDFORD DIV.	TYPE OF MACHINE: LR LATHE	JOB: 155MM XM804	
	ACCOUNT NO.	DRAWING NO. 18152	OPERATION NO. 160

T80 - AIR OPER. WORK DRIVER
T81 - NOSE SUPPORT
T82 - L.H. FACING TOOL
T83 - R.H. FACING TOOL
T84 - CAM ASSY
T111 - GROOVING TOOL
T112 - TURNING TOOL

927 - G85 DIAL SNAP 6.220 - .008
G86 DIAL SNAP 6.06 - .02
G322 TEMP. 3.485 + .015
G329 TEMPLATE .99 + .03 & .60 - .02
G303 TEMPLATE 2°30' + 1°0'
20° ± 3°



LET.	REVISIONS	DATE	BY		DWG. DATE 5-5-78 SUE R	SHEET 1 OF 1

CHAMBERLAIN Manufacturing Corporation NEW BEDFORD DIV.	TYPE OF MACHINE DETROIT BAND TESTER	JOB BODY, XM804 155MM	
	ACCOUNT NO.	DRAWING NO. 18152	OPERATION NO. 162

MAT'L: STL. FORGING

INSPECT BAND & BAND TIGHTNESS

LET.	REVISIONS	DATE	BY		DWG. DATE 5-5-78 SUE R	SHEET 1 OF 1

CHAMBERLAIN MANUFACTURING Corporation
NEW BEDFORD DIV.

TYPE OF MACHINE	JOB	
INSP. STAT "B"	155MM XM804	
ACCOUNT NO.	DRAWING NO. J8152-2	OPERATION NO. 168

DEFECT	GAGE NO	DEFECT	GAGE NO.
	MAJOR		MINOR
101	927-G85 DIAL SNAP (6.220-.008	208	927-G324 INDICATOR (MAX.01)
102	927 G307 ADJ BLADE SNAP (6.01±.01	209	927-G107 LENGTH (23.80-.20 STAT "A")
103	927-G88A TEMPLATE (3.48+-.03)	210	ROTATING BAND (VISUAL)
104	927-G65 TEMPLATE (.10+.04	211	SURFACE PROTECTION ON INDICATED SURFACES (VISUAL)
105	927-G86 DIAL SNAP 6.03 ±.01		
106	927-G312 CONC. GAGE ROTATING BAND RUNOUT (.016 TIM	212	WORKMANSHIP, RADII, BURRS, ETC. (VISUAL)
107	927-G113 HOWE SCALE (93.3±1.3 LB	213	IDENTIFICATION CORRECT & LOCATED PROPERLY (SCALE & VISUAL)
	MINOR		
201	912-G82 TEMPLATE (.10±.01		
202	927-G323 TEMPLATE (.59±.01)		
203	927 G303 TEMPLATE (2°30'+1°0'		
204	927-G65 TEMPLATE (20°±3°)		
205	927-G87A TEMPLATE (1.02-.04)		
206	912-G81 D.E. CYL. PLUG (.10±.01)		
207	WIDTH OF UCUT, FRT & REAR OF ROTATING BAND (MAX. .10)		
	TOOL CONTROL		

LET.	REVISIONS	DATE	BY	DWG. DATE	SHEET
				6-28-78	1 OF 1

Chamberlain Manufacturing Corporation, New Bedford Div.	TYPE OF MACHINE: SCHMIDT MKER	JOB: BODY, XM804 155 MM	
	ACCOUNT NO.	DRAWING NO. J8152	OPERATION NO. 170

T90 MARKING FIXTURE MAT'L STL FORGING
T91 TYPE ASSY.

CG01 -2-□□□□ 19□□ 155 MM XM804.

LOT NO

YR. OF MFG AS APPLICABLE

SEQUENCE TO BE CONSECUTIVE STARTING WITH NUMBER 1

NOTE:
STAMP ON CIRCUMFERENCE OF BODY, 1 INCH FORWARD OF ROTATING BAND SEAT, WITH LETTERS AND FIGURES. BOTTOM OF LETTERS TO BE TOWARD BASE OF SHELL.

LET.	REVISIONS	DATE	BY					DWG. DATE	SHEET
								SIE K 5-5-78	1 OF 1

Chamberlain Manufacturing Corporation New Bedford Div.	TYPE OF MACHINE CONV. BOND TANK	JOB BODY, XM804, 155MM	
	ACCOUNT NO.	DRAWING NO. 18152	OPERATION NO. 175

MAT'L:- STEEL FORGING

WASH, RINSE & BONDERIZE, SHELL

LET.	REVISIONS	DATE	BY	DWG. DATE	SHEET
				SUE R 5-6-78	1 OF 1

CHAMBERLAIN Manufacturing Corporation
NEW BEDFORD DIV.

TYPE OF MACHINE

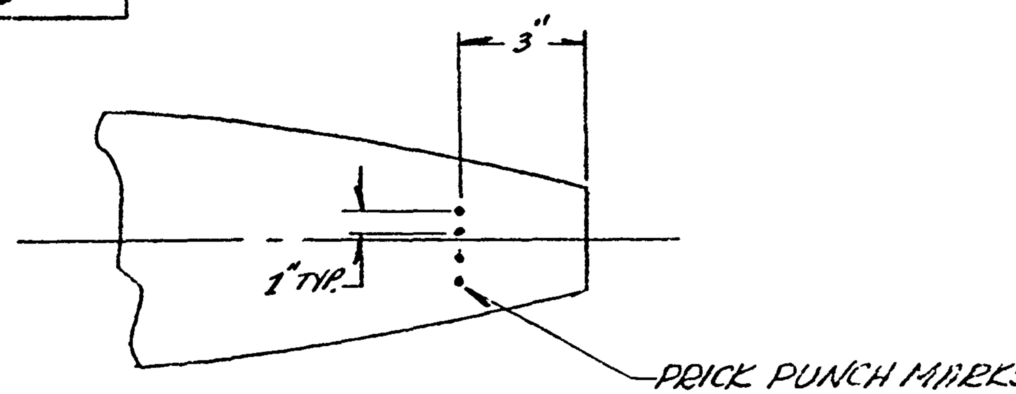
ACCOUNT NO.

JOB BODY, XM804, 155MM

DRAWING NO. J8152

OPERATION NO. 178

ZONE		WEIGHT	NO. OF MARKS
Z	2	90.0-91.3	• •
O	3	91.1-92.4	• • •
N	4	92.0-93.7	• • • •
E	5	93.3-94.6	• • • • •



WEIGH SHELLS 100% & MARK AS SPECIFIED
FOR WEIGHT ZONES LISTED

LET.	REVISIONS	DATE	BY	DWG. DATE	SHEET
				5-18-78	1 OF 1

CHAMBERLAIN Manufacturing Corporation NEW BEDFORD DIV.	TYPE OF MACHINE ECLIPSE PAINT	JOB BODY, XM804 ,155 MM	
	ACCOUNT NO.	DRAWING NO. J8152	OPERATION NO. 180

MAT'L :- STEEL FORGING

ASSEMBLE THD. MASK & PAINT CAVITY OF SHELL FINISH NO. 24.6 OF MIL-STD-171 (RED PRIMER - MIL-P-22332)

ALTERNATE: BLUE #35109 OF FED-STD-595, SPEC TT-E-516

LET.	REVISIONS	DATE	BY					DWG. DATE	SHEET
								SUE R 5-5-78	1 OF 1

CHAMBERLAIN MANUFACTURING Corporation NEW BEDFORD DIV.	TYPE OF MACHINE	JOB BODY, XM804 155MM SHELL	
	ACCOUNT NO.	DRAWING NO. J8152	OPERATION NO. 183

MAT'L: STEEL FORGING

T13 - INSPECTION LIGHT
VISUALS
G99 - THD. PLUG GAGE "GO"
G100 - " " " "NO GO"
DONE AT STA. "IA"

UNMASK INSPECT CAVITY

LET.	REVISIONS	DATE	BY	DWG. DATE	SHEET
				SUE R 5-5-78	1 OF 1

CHAMBERLAIN MANUFACTURING Corporation
NEW BEDFORD DIV.

TYPE OF MACHINE	JOB BODY, XM804, 155 MM	
ACCOUNT NO.	DRAWING NO. 18152	OPERATION NO. 185

7304 BRUSH ASSY

APPLY A MINIMUM OF COSMOLINE (GRADE 2 SPEC MIL-C-16173) TO FUZE THD. ONLY, LEAVING FUZE SEATING SHOULDER BARE & THD IN NOSE PLUG.

LET.	REVISIONS	DATE	BY	DWG. DATE	SHEET
				SUE R 5-5-78	1 OF 1

CHAMBERLAIN Manufacturing Corporation, New Bedford Div.	TYPE OF MACHINE: CONN. PAINT MACH	JOB: BODY, XM804 155 MM	
	ACCOUNT NO.	DRAWING NO.: J8152	OPERATION NO.: 190

T-102 MASKING SHIELD

MAT'L- STEEL FORGING

HANG SHELL MASK BAND & ELECTROSTATIC PAINT O.D. OF SHELL INCLUDING LIFTING PLUG.

COLOR # 35109, BLUE OF FED-STD 595

LET.	REVISIONS	DATE	BY					DWG. DATE	SHEET
								SUE R 5-5-78	1 OF 1

CHAMBERLAIN MANUFACTURING Corporation NEW BEDFORD DIV.	TYPE OF MACHINE INSP. STA.	JOB BODY XM804 155 MM	
	ACCOUNT NO.	DRAWING NO. 18152	OPERATION NO. 193

MAT'L STEEL FORGING

ALL VISUALS
G175 - PAINT THICKNESS GAGE .9 MIL MIN.
G103 - BOURRELET DIA (6.095 MAX.)

REMOVE MASK & INSPECT PAINT 100% VISUAL
NO PAINT ALLOWED ON INTERIOR OF SHELL
SAMPLE SALT SPRAY TEST
SAMPLE ADHEARION TEST

LET.	REVISIONS	DATE	BY				DWG. DATE 5-5-78 SUE R	SHEET 1 OF 1

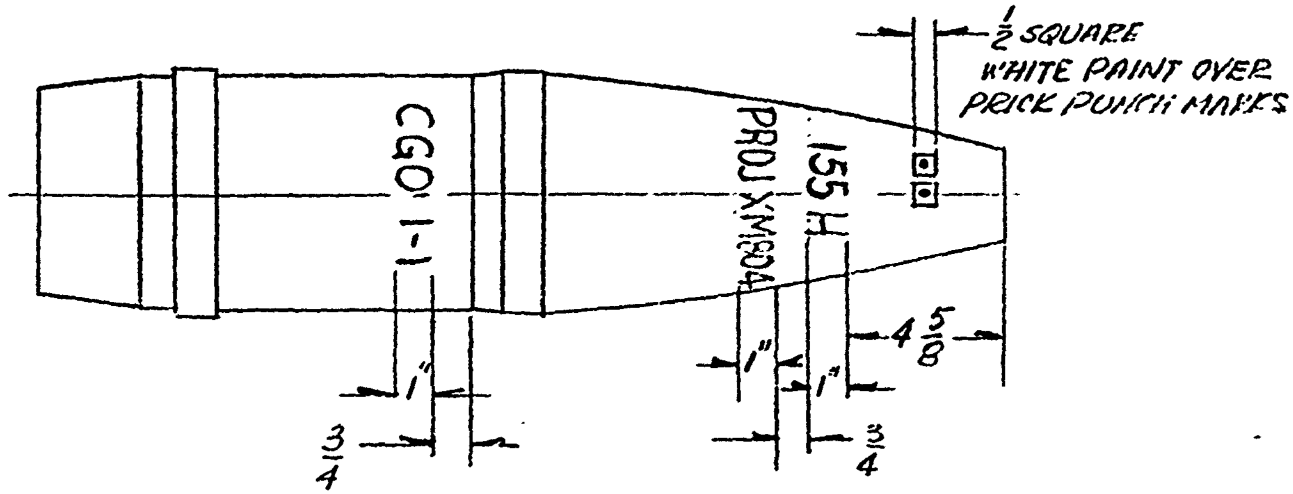
CHAMBERLAIN Manufacturing Corporation NEW BEDFORD DIV.	TYPE OF MACHINE WORK TABLE & CONV.	JOB BODY, XM804 155.MM	
	ACCOUNT NO.	DRAWING NO. 18152	OPERATION NO. 195

MAT'L STL. FORGING

UNLOAD CONVEYOR, PLACE GROMMET OVER BAND

LET.	REVISIONS	DATE	BY					DWG. DATE 5-5-78 SUE R	SHEET 1 OF 1

CHAMBERLAIN Manufacturing Corporation NEW BEDFORD DIV.	TYPE OF MACHINE	JOB BODY, XM804, 155MM	
	ACCOUNT NO.	DRAWING NO. J8152	OPERATION NO. 196



STENCIL MARKINGS

LET.	REVISIONS	DATE	BY		DWG. DATE	SHEET
					5-18-78	1 OF 1

CHAMBERLAIN Manufacturing Corporation, NEW BEDFORD DIV.	TYPE OF MACHINE: INSP STAT "C"	JOB: 155MM XM804	
	ACCOUNT NO.	DRAWING NO. J8152-3	OPERATION NO. 197

DEFECT	GAGE NO	DESCRIPTION
		CRITICAL
1	VISUAL	METAL DEFECTS, CRACKS, ETC.
		MAJOR
101	VISUAL	PAINT PER NOTE 2
102	804-G103	RING GAGE, BOURRELET DIA. MAX 6.098
103	VISUAL	CORRECT MARKING, INCLUDING LOT NUMBER AND SERIAL NUMBER
104	VISUAL	WEIGHT ZONE MARKING CORRECT AND WITHIN ZONE 4 OR 5
105	VISUAL	WORKMANSHIP, FOREIGN MATERIAL, DAMAGE, ETC.

LET.	REVISIONS	DATE	BY	DWG. DATE	SHEET
				6-29-78	1 OF 1

CHAMBERLAIN Manufacturing Corporation NEW BEDFORD DIV.	TYPE OF MACHINE	JOB BODY X.M804	155MM.
	ACCOUNT NO.	DRAWING NO. J8152	OPERATION NO. 198

PALLETIZE SHELL

LET.	REVISIONS	DATE	BY	DWG. DATE	SHEET
				5-5-78 SUE R	1 OF 1

CHAMBERLAIN Manufacturing Corporation NEW BEDFORD DIV.	TYPE OF MACHINE HAND STRAPPING	JOB BODY, XM804	155 MM
	ACCOUNT NO.	DRAWING NO. 18152	OPERATION NO. 200

3/4 X .020 STEEL STRAPPING

BAND PALLETS

VISUALLY INSPECT PALLETS FOR:

MARKING
CONFORMING TO SPEC.
GROMMET IN PLACE

LET.	REVISIONS	DATE	BY					DWG. DATE 5-5-78 SUE R	SHEET 1 OF 1

APPENDIX B

XM804 PROJECTILE STRESS ANALYSIS

CHAMBERLAIN MANUFACTURING CORPORATION

RESEARCH & DEVELOPMENT DIVISION

Document No. C8152-ED-001

Issue Date: 29 June 1978

Revision A: 14 July 1978

STRESS ANALYSIS

155-MM, XM804 TRAINING PROJECTILE

	DATE	REV	DATE	REV	DATE	REV
Prepared by: J. Mauceri	7-14-78	A				
Reviewed by: Dennis D. Kaiser						
Approved:						

STRESS ANALYSIS

XM804 155 MM Training Round

DRAWING NO. J8152-2

DATE: 9 May 1978

CONTRACT: DAAK10-78-C-0072

REPORT: J. Manross

INTRODUCTION:

An analysis was performed to verify that the XM804 "heavy wall" projectile, J8152-2, will safely withstand the gun environment associated with a Charge Zone 5 firing. Because it may some day become desireable to fire this projectile at a higher Charge Zone, the analysis was extended to include Charge Zone 7 conditions.

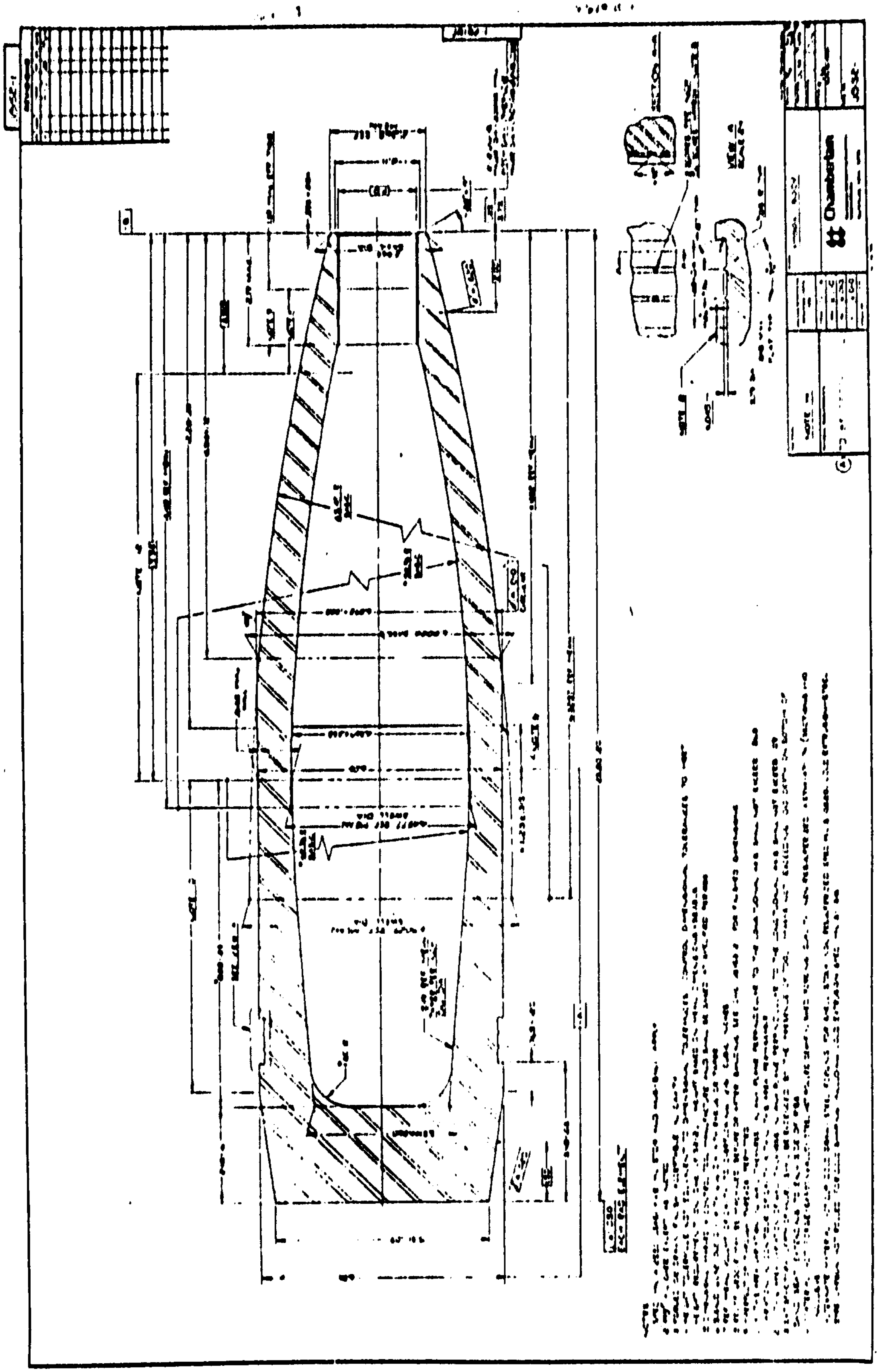
The Hencky-Von Mises (maximum distortion energy) theory was used to resolve the major principal stresses permitting a direct comparison with the material yield strength to determine if plastic deformation will occur. To be sure that the applied procedures, assumptions, and theories were reasonable, the standard M107 H.E. projectile was analyzed at the point where the highest stress condition is predicted in the XM804.

Based on the analysis, the XM804 design (fabricated from non-heat treated AISI 1340 steel) should withstand a Zone 5 firing with a wide margin of safety. It appears that the ability of the design to survive a Zone 7 firing would best be determined by progressive gun firings.

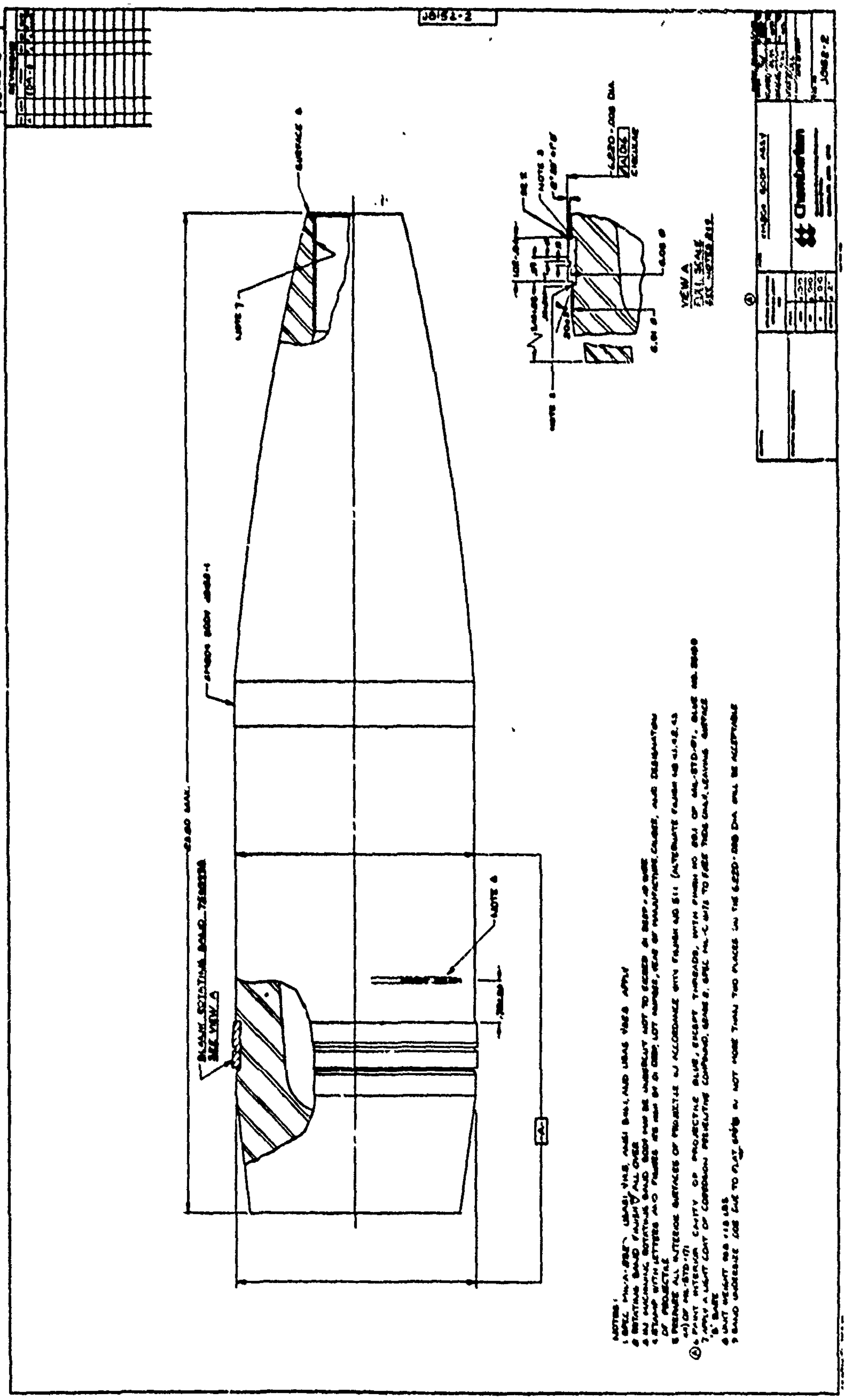
PROCEDURE

Walls

The stress analysis method employed was similar to the methods given in the Engineering Design Handbook "Design For Projection" of the Ammunition Series,



Best Available Copy



AMCP 706-247 and "Projectile Design Notes" prepared by R.M. Schwartz at ARRADCOM facilitated the analysis

Gun firing data for the M107 projectile published in U.S. Army Aberdeen Proving Ground Report No. APG-MT-4503 (AD B000335) was used to establish the loads which the XM804 projectile would encounter during gun firing tests. The following tabulation lists the pertinent data necessary to begin the analysis.

CHARGE ZONE	BASE PRESSURE PSI	MUZZLE VELOCITY FT./SEC.	TWIST	LAND DIA. IN.	BASE AREA IN.^{2}	CALCULATED XM804 ACCELERATION G's
7	34,560	1841	1/20	6.1	29.81	10,855
6	20,230	1519	1/20	6.1	29.81	6,354
5	13,010	1240	1/20	6.1	29.81	4,086

The list of symbols on the following page identifies the various symbols used in the stress formulas.

Stress locations were as follows:

(1) Section at minimum wall thickness of projectile (near ogive). - Location (A)

(2) Section plane just forward of the projectile rotating band. - Location (B)

(3) Section plane at aft side (BASE) of rotating band. - Location (C)

(4) Section plane through base at bottom of interior cavity. - Location (D)

STRESS IN SHELL

LIST OF SYMBOLS

SYMBOL		UNIT
S_c	Flexural Stress-Center	Lbs./In.^{2}
S_r	Flexural Stress-Radial	Lbs./In.^{2}
S_t	Flexural Stress-Tangential	Lbs./In.^{2}
A	Area of bore of gun	sq. in.
A_B	Area of assumed shear circle in base of shell	in.^{2}
d	Diameter of bore of gun (across lands)	in.
d_1	Inside diameter of projectile	in.
D	Diameter of assumed shear circle in base of shell	in.
F_S	Maximum force on base of projectile closure	lb.
G	Total Acceleration of Systems	G's
n	Twist of Rifling	Calibers/Turn
P	Base Propellant Pressure	Lbs./In.^{2}
H	Depth of filler from nose end of cavity to section under consideration	in.
$P_o h$	Filler pressure due to setback	lb. per sq. in.
$P_o r$	Filler pressure due to rotation	lb. per sq. in.
R_o	Inside radius of projectile	in.
R_1	Outside radius of projectile	in.
ST_1, ST_2, etc.	Tangential Stresses (Component)	Lbs./In.^{2}
SR_1, SR_2	Radial Stresses (Component)	Lbs./In.^{2}
T	Base Thickness	in.
S_S	Shear Stress	Lbs./In.^{2}
o	Density of Filler Charge	Lbs./In.^{3}
V	Muzzle velocity	ft. per sec.
W	Total projectile weight	lb.
W'	Weight of metal parts forward of section considered	lb.
W_B	Weight of Base Closure	
S_{Max}	Von Misses Maximum Resultant Stress	
S_1	Summation of Longitudinal Stress	
S_2	Summation of Radial Stress	
S_3	Summation of Tangential Stress	

The following basic formulas were used to determine the two major dynamic stresses on an empty XM804 Projectile and the resultant maximum stress was determined by the Hencky-Von Mises Theory. The major stresses acting on an empty projectile (without filler) are a longitudinal (axial) compressive stress caused by setback of the metal parts forward of the stress location and a tangential (hoop) tensile stress caused by rotation of the metal parts (wall) and a tangential compressive stress caused by the base pressure <u>where applicable</u>.

S_1 = Longitudinal stress - Setback of metal parts - Compressive

$$S_1 = \frac{W'PA}{\pi(R_1^2 - R_o^2)W}$$

S_3 = Sum of tangential stress = $S_{T1} + S_{T2}$

S_{T1} = Metal Parts rotation - Tensile

$$S_{T1} = +\,1.04\left(\frac{R_1 + R_o}{d}\right)^2\left(\frac{V}{n}\right)^2$$

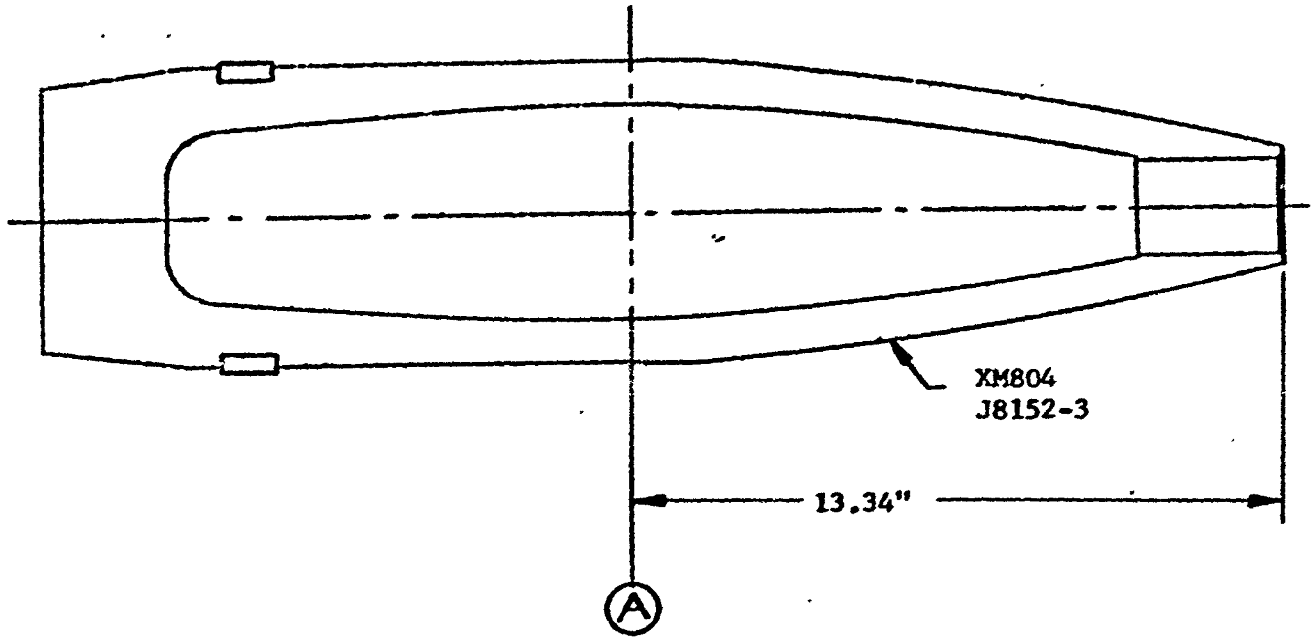
S_{T2} = External pressure (locations aft of rotating band) - Compressive

$$S_{T2} = -\,P\left(\frac{2R_1^{\;2}}{R_1^{\;2} - R_o^{\;2}}\right)$$

Hencky-Von Mises Yield Function (Resolved Maximum Stress)

$$S_{MAX} = \sqrt{\frac{(S_1-S_2)^2 + (S_1-S_3)^2 + (S_2-S_3)^2}{2}}$$

Figure Nos. 1 through 6 identify the specific locations where the stresses were determined and the values of the stresses at a particular charge zone.



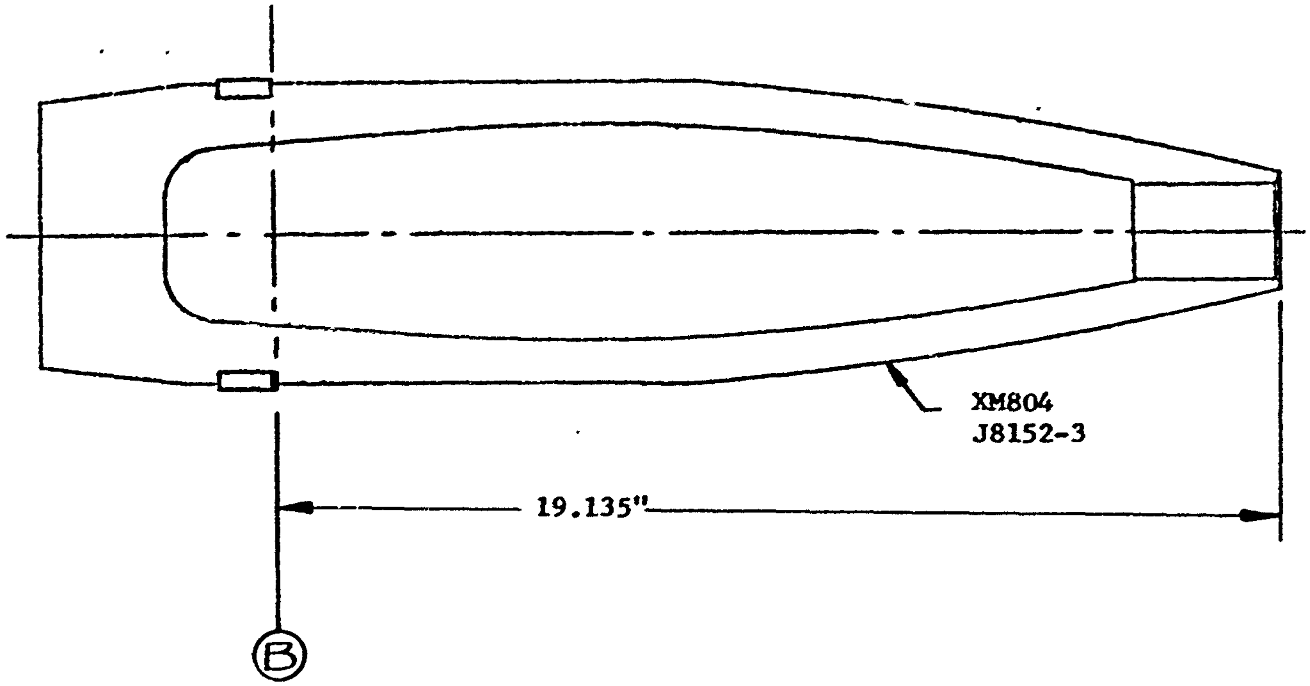
Section at minimum wall thickness @ Charge Zone 7.

Longitudinal stress (setback of metal wall) = -32,896 PSI compressive stress.

Tangential stress (Rotation of Metal Wall) = +6,519 PSI tensile stress.

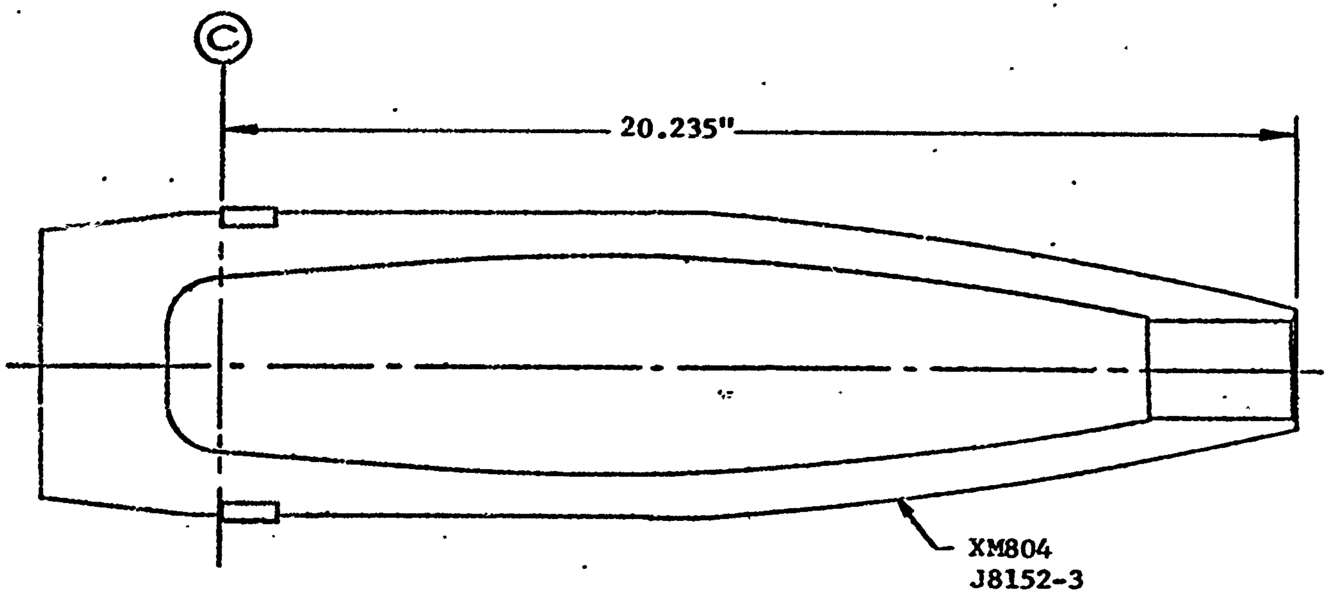
Von Mises Yield Function = 32,600 PSI maximum stress.

FIGURE 1



Section plane just forward of the projectile rotating band @ Charge Zone 7.
Longitudinal stress (setback of metal wall) = -38,975 PSI compressive stress.
Tangential stress (Rotation of metal wall) = +5,617 PSI tensile stress.
Von Mises Yield Function = <u>42,100 PSI maximum stress.</u>

FIGURE 2



Section plane at aft side of rotating band

Charge Zone 7

Longitudinal stress (setback of metal wall) = -40,635 PSI compressive stress.

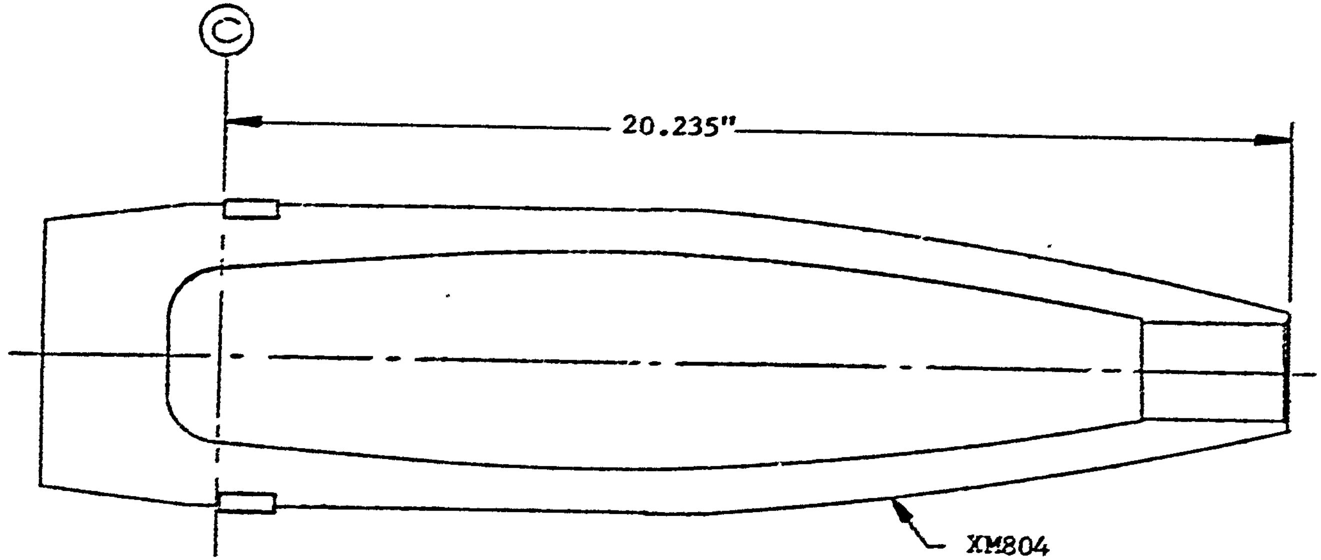
Summation of tangential stress = -103,827 PSI compressive stress.

Tangential stress (Rotation of wall) = +5,421 PSI tensile stress.

Tangential stress (External pressure) = -109,248 PSI compressive stress.

Von Mises Yield Function - 90,600 PSI maximum stress.

FIGURE 3



Section plane at aft side of rotating band

Charge Zone 6

Longitudinal stress (setback of metal wall) = -23,786 PSI compressive stress.

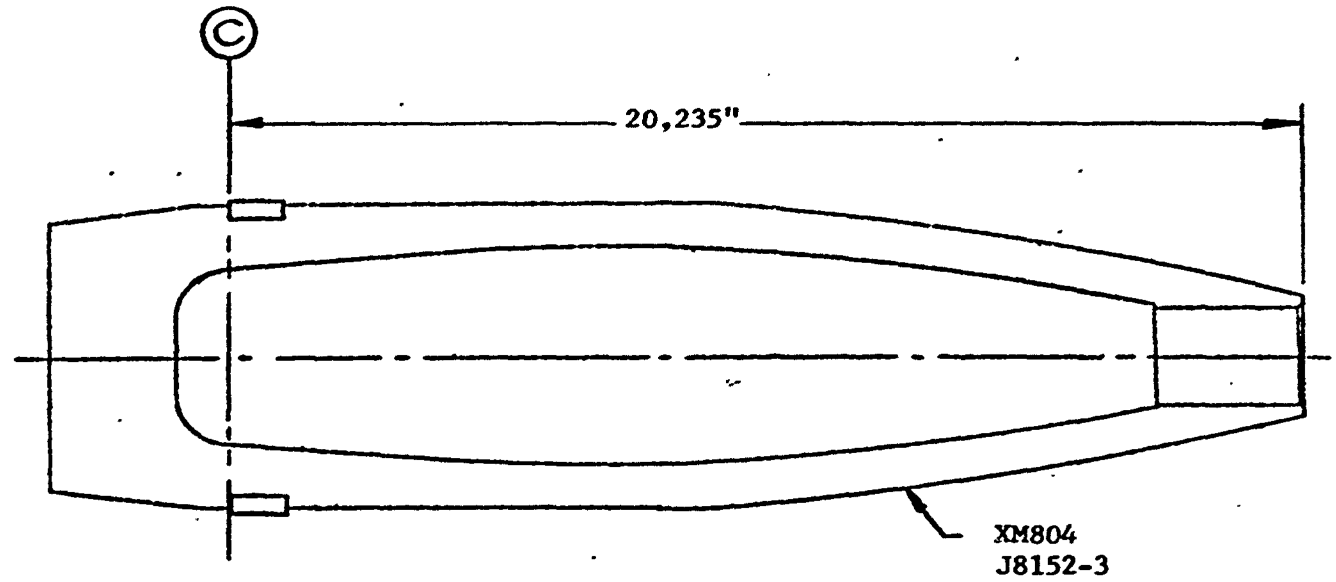
Summation of tangential stress = -60,258 PSI compressive stress.

Tangential stress (Rotation of wall) = +3,691 PSI tensile stress.

Tangential stress (External pressure) = -63,949 PSI compressive stress.

Von Mises Yield Function = 52,600 PSI maximum stress.

FIGURE 4



Section plane at aft side of rotating band.

<u>Charge Zone 5</u>

Longitudinal stress (setback of metal wall) = -15,270 PSI compressive stress.

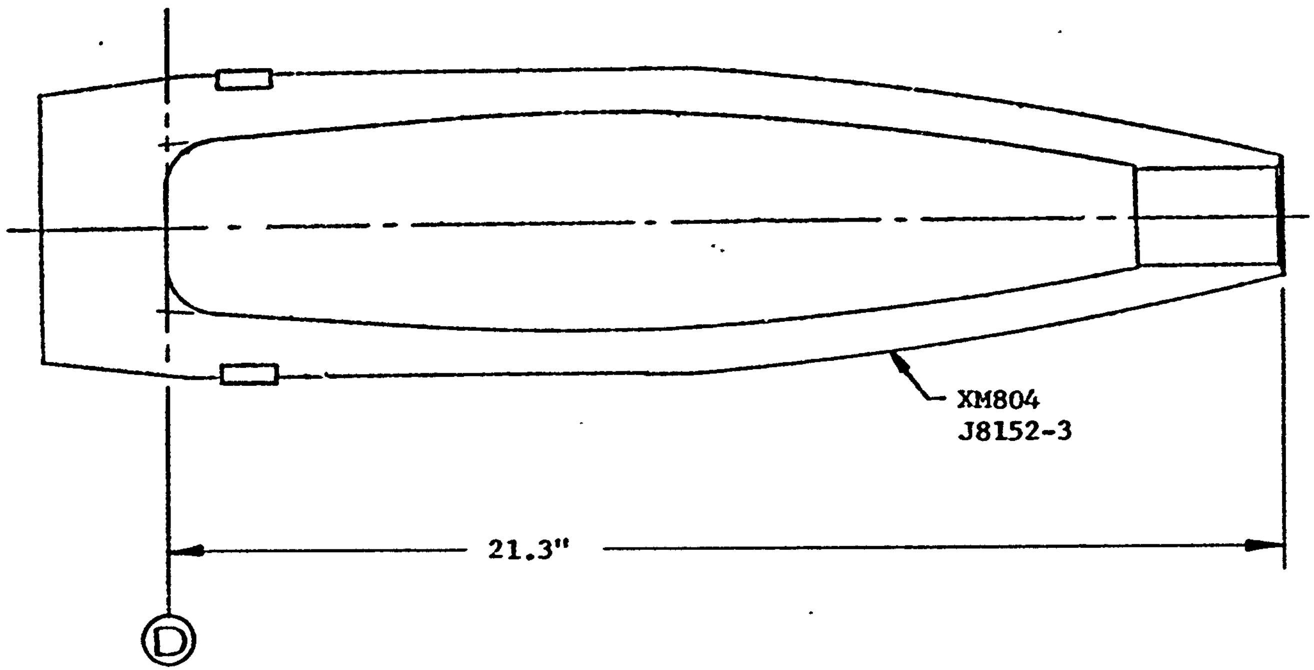
Summation of tangential stress = -38,667 PSI compressive stress.

Tangential stress (Rotation of wall) = +2,459 PSI tensile stress.

Tangential stress (External pressure) = -41,126 PSI compressive stress.

Von Mises Yield Function = <u>33,800 PSI maximum stress.</u>

FIGURE 5



Section plane through base at bottom of interior cavity @ Charge Zone 7.

Longitudinal stress (setback of metal wall) = -44,433 PSI compressive stress.

Summation of tangential stress = -95,818 PSI compressive stress.

Tangential stress (Rotation of wall) = +5,121 PSI tensile stress.

Tangential stress (External pressure) = -100,939 PSI compressive stress.

Von Mises Yield Function = 83,000 PSI maximum stress.

FIGURE 6

The M107 HE Projectile stresses were analyzed at the same location where the stresses on the XM804 were determined to be the greatest. This location was directly behind the rotating band of the XM804. (Refer to Figure 7.) One additional major stress must be determined for the M107, which is caused by the HE filler in the projectile. This radial stress is caused by the HE filler assumed to be acting as a liquid during acceleration and producing a hydraulic force on the interior wall of the projectile. The longitudinal stress (S_1) formula remains the same. The tangential stress (S_3) was expanded to include the additional tangential component caused by the HE filler. Radial stress is determined as follows:

S_2 = Sum of Radial Stress caused by the additive force of filler setback and filler rotation - Compressive

$$S_2 = S_{R1} + S_{R2}$$

S_{R1} = filler setback pressure on the projectile side wall ($P_o{}^h$)

$$S_{R1} = P_o{}^h = -\rho HG$$

S_{R2} = filler rotation pressure ($P_o{}^r$)

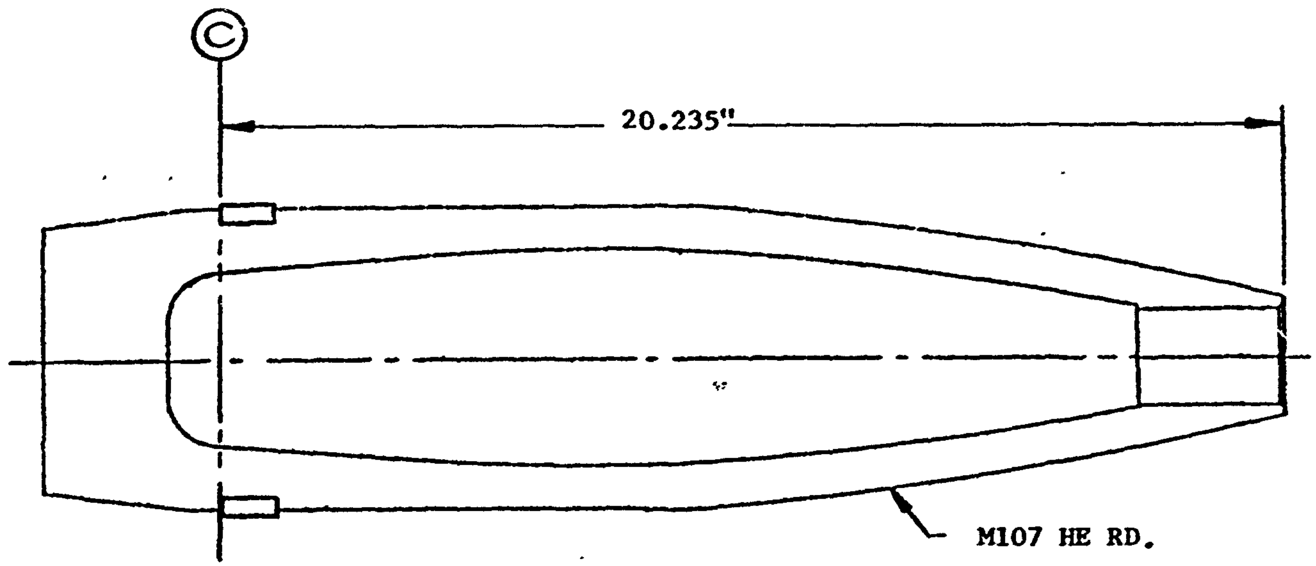
$$S_{R2} = P_o{}^r = -1.84\,\rho\left(\frac{V}{n}\right)^2\left(\frac{d_1}{d}\right)^2$$

The additional tangential component which must be added to S_3 is S_{T3} therefore S_3 = sum of S_{T1}, + S_{T2}, + S_{T3}

S_{T3} = Hoop stress from filler pressure - Tensile

$$S_{T3} = +\left(P_o{}^h + P_o{}^r\right)\left(\frac{R_1{}^2 + R_o{}^2}{R_1{}^2 - R_o{}^2}\right)$$

Note that S_{T3} is a beneficial component of the tangential stress. Although the External pressure tangential component (S_{T2}) is greater than on the XM804, the positive value of S_{T3} reduces the overall value of the summation, S_3. Refer to Figure 7 for the pertinent values of stresses.



<u>M107 W/HE FILLER @ CHARGE ZONE 7</u>

Section plane at aft side of rotating band

<u>Longitudinal</u> stress (setback of metal wall) = -34,392 compressive stress.

Summation of <u>Radial</u> stress = -12,209 PSI compressive stress.

Radial stress (Filler setback pressure transmitted to wall) = -11,879 PSI compressive stress.

Radial stress (Filler rotation pressure) -330 PSI compressive stress.

Summation of <u>tangential</u> stress = -80,400 PSI compressive stress.

Tangential stress (internal stress from filler pressure) = +28,080 PSI tensile stress.

Tangential stress (Rotation of wall) = +5,564 PSI tensile stress.

Tangential stress (external pressure) = -114,045 PSI compressive stress.

Von Mises Yield Function = <u>60,600 PSI maximum stress.</u>

FIGURE 7

Base Closure

Shear and flexural stresses at the base end of the projectile were determined as though the location was a cylindrical "plug" rigidly attached to the "wall". Area (E) on Figure 8 identifies the location and dimensions of the "plug". Stresses were calculated at a gun firing environment of Charge Zone 7.

Shear Stress was determined from the following formula:

$$S_S = \frac{F_S}{A_{SHEAR}} = \frac{PA_B - WG}{\pi DT}$$

Standard "flat plate" formulas assuming rigid support were used to determine flexural stress at the "edge" of the assumed cylindrical diameter and at the center.

Flexural Stress at "EDGE"

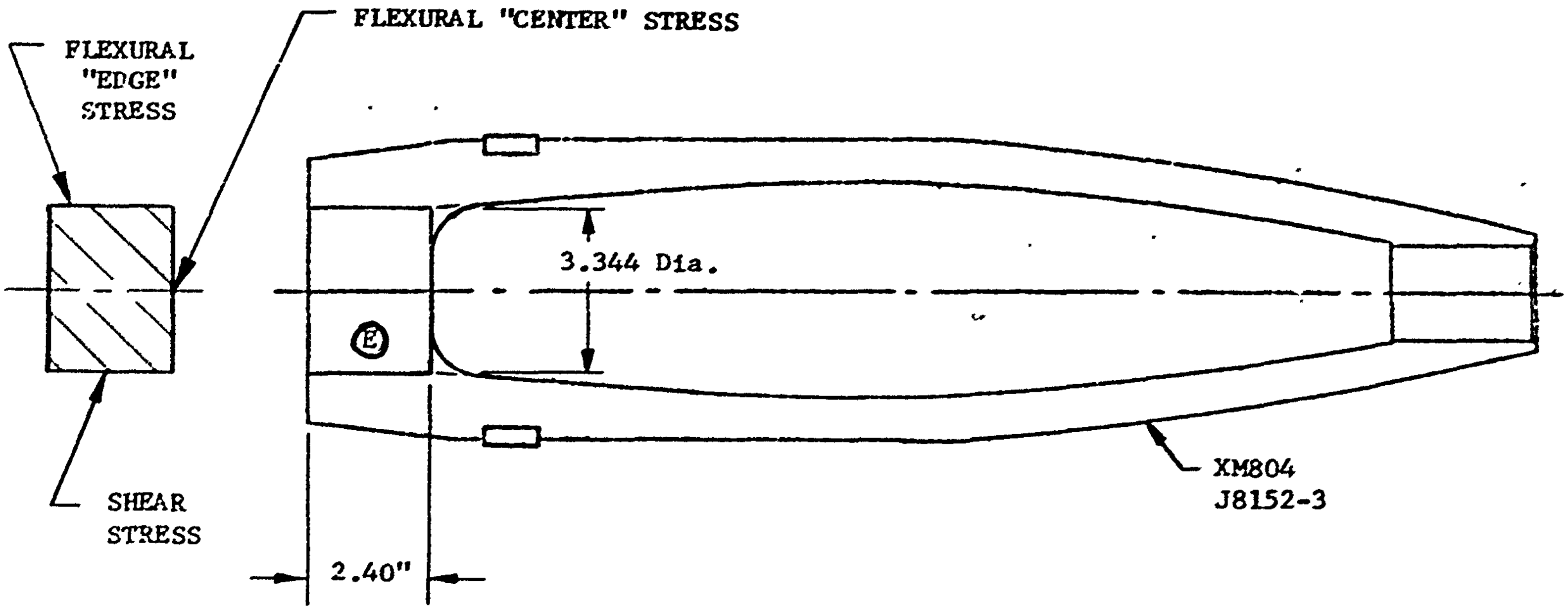
$$S_r = \text{Flexural Stress Radial (Compressive Stress)} = -\frac{3F_s}{4\pi T^2} = \frac{3(PA_B - WG)}{4\pi T^2}$$

$$S_t = \text{Flexural Stress Tangential (Tensile Stress)} = +\frac{F_s}{4\pi T^2} = \frac{PA_B - WG}{4\pi T^2}$$

Flexural Stress at Center

At the Center, $S_r = S_t = S_{\text{Center flexural stress}}$

$$S_c = \frac{F_S}{2\pi T^2} = \frac{PA_B - WG}{2\pi T^2}$$



Cylindrical section at base of projectile (metal "plug") @ Charge Zone 7

Shear stress = 9,470 PSI.

Flexural stress at "edge" (Circumference) - (Flat Base).

Radial flexural stress = -9,896 PSI compressive stress.

Tangential flexural stress = +3,299 PSI tensile stress.

Flexural stress at center - (Flat Base) ($S_r = S_t$ @ center).

Center stress = 6,598 PSI.

FIGURE 8

TABULATION OF DATA

TYPE OF STRESS		XM804							M107
	ZONE	7	7	7	6	5	7	7	7
	LOCATION	A	B	C	C	C	D	E	C
	FROM NOSE	13.34"	19.135"	20.235"	20.235"	20.235"	21.3"	BASE "PLUG"	20.235"
LONGITUDINAL		32.9	39.0	40.6	23.8	15.3	44.4		34.4
TANGENTIAL		6.5	5.6	103.8	60.3	38.7	95.8		80.4
RADIAL									12.2
SHEAR								9.5	
FLEXURAL-EDGE (RADIAL)								9.9	
FLEXURAL-EDGE (Tang.)								3.3	
FLEXURAL-CENTER								6.6	
VON MISES YIELD		36.6	42.1	90.6	52.6	33.8	83.0		60.0

* Stresses Rounded to Nearest 1000 PSI

CONCLUSIONS

The area of greatest stress on the XM804 "heavy wall" design, J8152-2, appears to exist at the aft side (base) of the rotating band which is 20.235" (mean dimension) from the nose. Stress calculations were based on the premise that external propellant pressure would impinge directly on the 5.79" diameter or undercut diameter for the rotating band of the projectile.

At charge Zone 7 the steel in this area could, but not necessarily would, begin plastic deformation if the material yield point was less than 90,600 PSI. At Zone 6 the material yield point should be >52,600 PSI and at Zone 5 the material yield point should be >33,800 PSI to avoid possible plastic deformation.

At Zone 5 the XM804 projectile, fabricated from AISI 1340 steel (non-heat treated) with an annealed yield point of approximately 63,000 PSI, should not experience plastic deformation. A material yield of 63,000 PSI versus a calculated stress of 33,800 PSI implies a safety factor of almost 2/1 before plastic deformation would occur on the XM804 projectile.

It was assumed that the greatest stress of the M107 HE round would also occur at the aft side of the rotating band since the XM804 design is very similar to the M107. The M107 Zone 7 stress (Von Mises Function) at this location was calculated to be 61,000 PSI which correlates very well with a minimum material yield requirement of 65,000 PSI for the M107 projectile.

RECOMMENDATIONS

The XM804 training projectile should be limited to the maximum stress of Charge Zone 5 at the present time.

After extensive tests at Zone 5 with no evidence of metal parts integrity problems, incremental testing to achieve a higher charge Zone should be possible.

APPENDIX C

XM804 PROJECTILE COST ESTIMATES

XM804 PRESSURE CASTING COST ESTIMATES

Summarized on the following page are estimated costs of producing a pressure-cast XM804 Projectile as determined by Reynolds Engineering, Inc., the originator of the process, and by Chamberlain R&D. Reynolds' original estimates were based on material and equipment costs which were approximately five years old while Chamberlain's estimates with the aid of Reynolds Engineering were based on a study conducted during the performance of the subject contract (DAAK10-78-C-0072). Chamberlain's estimate is detailed by item number on Pages 112 through 120 and their labor rates considered in their estimate were for personnel required to operate the sample production line shown by the layout drawing on Page 121; however, equipment costs were not considered. It will be noted that a normalizing furnace was included in this layout assuming a heat-treating requirement. The original cost analysis indicated a cost savings of approximately 2/3 for the pressure-cast shell over the forged shell but this predicted saving later was revised to a potential 10% to 12% saving based on experience during the program.

The following additional information is included in the remainder of this Appendix:

Machining Cost Estimate, J8152-4 Casting
Scranton Production Cost Estimate, M107
Scranton Production Cost Estimate, XM804
New Bedford Production Cost Estimate, XM804
Lynchburg Foundry Cost Estimate, Sand-Cast M107
ARRADCOM Cost Analysis for Inert Loading

PRODUCTION COST ESTIMATE

XM804 CASTING
J8152-4

(WITHOUT FINISH MACHINING COSTS)

ITEM NO.	ORIGINAL REYNOLDS ENG. INC.	DESCRIPTION	REVISED BY CMC R&D DIV.
1.	$4.36	Casting Material	$8.55
2.	$ .53	Core Material	$1.40
3.	$3.07	Labor & OH	$10.20
4.	$1.10	Power	$3.08
5.	$ .45	Other	$ .45
6.	$ .40	Mold & Core Box	$ .75
7.	$ .92	Capital Equipment	$ .0
8.	$ .50	Misc. (G&A, Takes, Ins. Etc.)	$2.08
9.	$ .57	Contingency	$ .0
10.	$ .95	Profit	$2.65
	$12.85	TOTAL	$29.16

PRODUCTION COST ESTIMATE

XM804 CASTING
J8152-4

ITEM NO. 1

123.4 Lbs. (Net Casting) x 1.1 (10% Melting Loss) = 135.7 $\frac{\text{lbs.}}{\text{Proj.}}$

SCRAP:

$99/Ton In Chicago for Structural 2' Lengths Max.

or 5¢/Lb.

SHIPPING:

0.7¢/Lb. Rail Car from Chicago to Waterloo

ADDITIVES:

$12/Ton or $\frac{12}{2000}$ = .006 0.6¢/Lb.

(See Note #1)

TOTAL COST: = 0.05 + .007 + .006 = 0.063/Lb.

135.7 x .063 = 8.549 or $8.55/Proj.

NOTE: Additive costs from Vulcan Foundry, San Francisco, Calif. - 19 July 1978

ferrous silicon	$4½ - 6/ton
ferro-manganese	$4.20/ton
calcium silicon	$1.20/ton
aluminum	$1.20/ton
TOTAL	$11.10-12.60/ton

PRODUCTION COST ESTIMATE

XM804 CASTING
J8152-4

ITEM NO. 2

ASSUMPTION: No Reclaim

SAND $150/Ton F.O.B. Florida + $30/Ton Shipping

for a Total of $180/ton or 9¢/lb.

RESIN $40/Ton or 2¢/lb.

15.4 lb. Sand + .6 lbs. Resin = 16 lb. core

15.4 x .09 = $1.39 for sand

0.6 x .02 = $ .01 for Resin

$1.40

PRODUCTION COST ESTIMATE

XM804 CASTING
J8152-4

ITEM NO. 3

ASSUMPTIONS: 80 Hr. Vacations
12 Holidays for 96 Hrs.
2080 - 176 = 1904 Hrs/Man Yr.
May 1978 Dollars, Cost of Money and Overheads at R&D

PLANT OPERATION

(EM)	SUP	1 x 1904 x 15.13	$28,808
(PE)	FOREMAN	3 x 1904 x 8.47	$48,381
(PM)	METALLURGIST	1 x 1904 x 12.42	$23,648
(SE)	LAB TECH	3 x 1904 x 7.62	$43,525
(SHOP)	LABOR	31 x 1904 x 7.27	$429,104
(INSP)	INSPECTORS	4 x 1904 x 7.12	$54,226
		PLANT DIRECT TOTAL	$627,692
(Includes Cost of Money) 172% OH			$1,079,630
		TOTAL	$1,707,322

$$\frac{\$1,707,322}{200,000 \text{ Proj.}} = \$8.54/\text{Proj.}$$

PRODUCTION ENGINEERING

PM	1 x 1904 x 12.42	$23,648
SPE	1 x 1904 x 10.28	$19,573
PE	1 x 1904 x 8.47	$16,127
ET	1 x 1904 x 6.62	$12,604
		$71,952

PRODUCTION COST ESTIMATE

XM804 CASTING
J8152-4

ITEM NO. 3 (Continued)

QUALITY CONTROL ENGINEERING

SPE	1 x 1904 x 10.28	$19,573
PE	1 x 1904 x 8.47	$16,127
SE	1 x 1904 x 7.62	$14,508
		$50,208
	TOTAL DIRECT ENGINEERING	$122,160
	172% OH	$210,115
	TOTAL	$332,275

$$\frac{\$332,275}{200,000 \text{ Proj.}} = \$1.66/\text{Proj.}$$

TOTAL LABOR:

Plant Operation		$8.54
Engineering		$1.66
	TOTAL	$10.20

PRODUCTION COST ESTIMATE

XM804 CASTING
J8152-4

ITEM NO. 4

POWER

30 KW-HR. MELTING FURNACE (24.8 Min. to 38.5 Max.)
Mark's Handbook Data

8.7 KW-HR. HOLDING FURNACE

$$\frac{200 \text{ KW} \times 8736 \text{ HRS.}}{200{,}000 \text{ Proj.}}$$

0 NO SAND RECLAIM

35.4 KW-HR. NORMALIZING FURNACE

$$\frac{121000 \text{ BTU}}{\text{PROJ.}} @ \text{ Scranton} \times 2.928 \times 10^{-4}$$

$$74.1 \text{ KW-HR.} \times 4.157 \frac{¢}{\text{KW-HR}} = \$3.08$$

PRODUCTION COST ESTIMATE

<u>XM804 CASTING</u>
J8152-4

<u>ITEM NO. 5</u>

SAME AS REYNOLDS ENGRG., INC. - $ 0.45

<u>Cost Item No. 5, Operating Cost, Other</u>

- Relining of Melting Furnaces: ($3,600./Relining)/(10 tons/ht)(80 hts)
  (18 Castings/ton)

  = $3,600/14,400 Castings per Lining

  = <u>25¢/casting</u>

- Supplies (Argon Gas, Cutoff Wheels, Abrasive Shot Makeup, etc.) --
  Estimated at 20¢/casting

PRODUCTION COST ESTIMATE

XM804 CASTING
J8152-4

ITEM NO. 6

MOLDS:

$700 Material
$700 Machining

$1400 Current (Maybe)

Half Price in Production = $700

Assume 1000 Castings/Mold

$\frac{\$700}{1000}$ = $0.70/Proj.

COREBOX: Same as RKR 5¢

TOTAL = $.75/Projectile

PRODUCTION COST ESTIMATE

XM804 CASTING
J8152-4

ITEM NO. 8

G&A @ 8½%

24.43 x .085 = 2.08

(SUBTOTAL OF 1 THRU 7)

PRODUCTION COST ESTIMATE

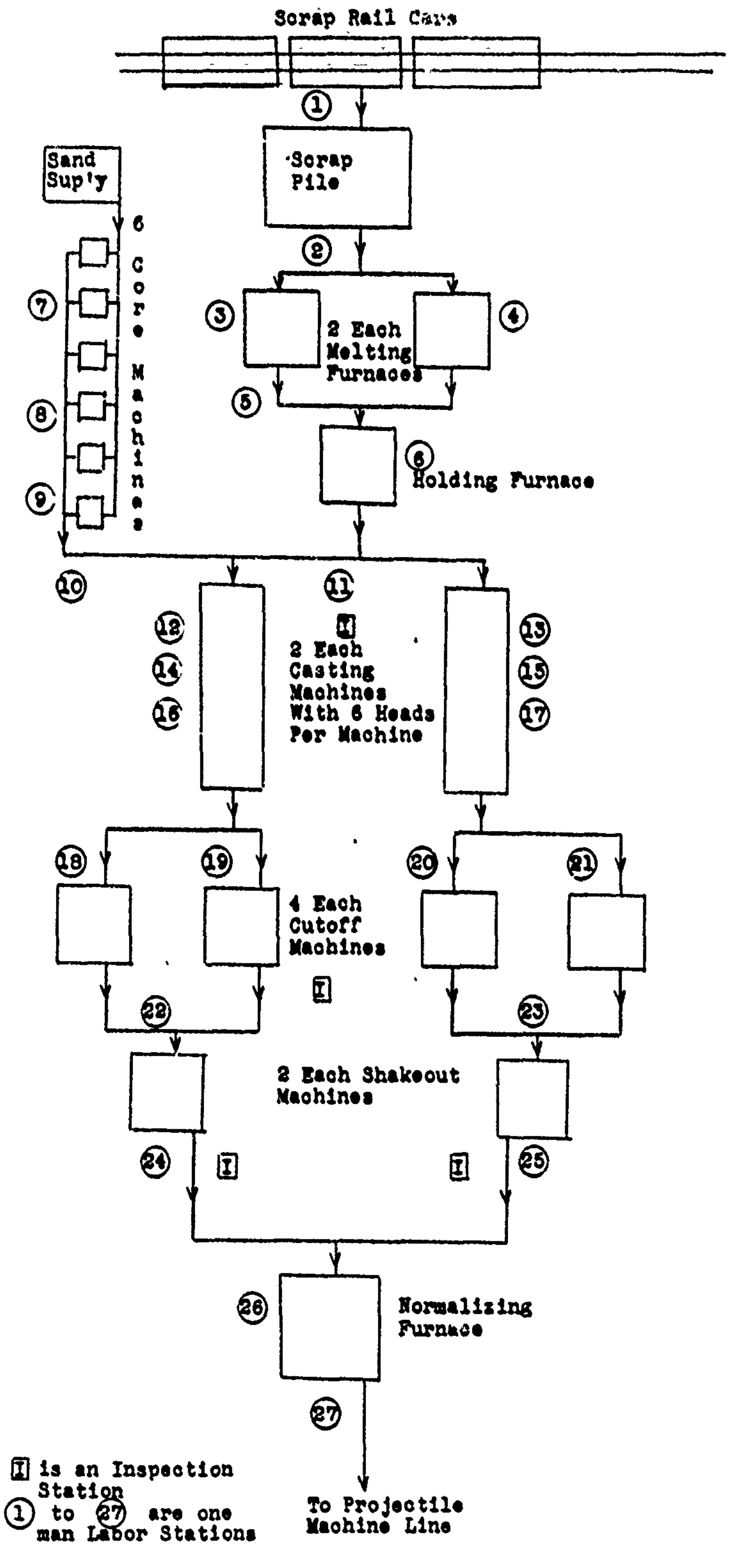
XM804 CASTING
J8152-4

ITEM NO. 10

Profit @ 10%

$26.51 x .10 = $2.65

(SUBTOTAL OF 1 THRU 9)



I is an Inspection Station
1 to 27 are one man Labor Stations

Labor Stations 28 to 31 are not shown but are backup and cleanup personnel

SAMPLE PRODUCTION LINE FOR XM804 PRESSURE CASTINGS

9 June 1978

MACHINING
COST ESTIMATE

XM804 PROJECTILE MANUFACTURED FROM A CASTING, J8152-4

Chamberlain New Bedford Division

	Cost/Round	$ June 78
1.	Casting	GFM
2.	Rotating Band	1.93
3.	Pallet	1.35
4.	Labor	1.40*
5.	Burden at 200%	2.80
6.	Tooling and Startup	1.58**
7.	G&A at 8%	.72
8.	Profit at 10%	.98
9.	Total Cost	10.76

Premise:

10. FOB at Division
11. Government-furnished grommets and lifting plug.
12. No heat treat of projectile.
13. Production rate of 200,000 each/year/5 years

* Current estimate based on 180 rounds at New Bedford for machining of round.

Chamberlain Scranton Division

A. August 76 M107 Production Cost $42.82/Round

B. Year 1977 M107 Forging and Material Cost = $31.55***

C. $42.82 - 31.55 = $11.27 Machining Cost Only

D. M107 TP Quote = $53.07 at 17,000 Each/Month (1978 Price)

E. $53.07 ÷ $42.82 = 1.239 Escalation Factor (Aug 76 to Jun 78)

F. $11.27 x 1.239 = $13.97

G. Total Cost = $13.97/Round

Premise:

Same as New Bedford.

*** The $31.55 includes the cost of heat treatment.

$$** \frac{\text{(Tooling at 2.25 + Startup at 5.67)(First 200,000 Rounds)}}{\text{1,000,000 Rounds}}$$

26 June 1978

CHAMBERLAIN SCRANTON DIVISION PRODUCTION COST ESTIMATE

STANDARD M107 MODIFIED FOR TRAINING (INERT)

1. AISI 1046 steel.
2. Heat treated to 65,000 psi.
3. Same interior cavity (may use M107 rejects also).
4. Phosphate coated and painted (red oxide on inside).
5. No base cover and without inert fill.
6. Ballistic lot samples: 20 rounds/20,000 each ($0.045/round less if samples not wanted).
7. Government-furnished grommets and lifting plug.
8. Government-furnished utilities (would be $4/round more if utilities were required).
9. FOB Scranton.
10. Premise: Training round must duplicate most of the M107 features because of possibility of mix-up with standard M107 HE on production lines.
11. Concurrent production of 50,000 each standard M107/month.
12. <u>Price</u>: $53.07 each at 17,000 each/month (204,000/year).
    $46.86 each at 20,000 to 22,000 each/month (most economical rate) (264,000/year).

+ 2.37 each FOR INERT FILL.

26 June 1978

CHAMBERLAIN SCRANTON DIVISION PRODUCTION COST ESTIMATE

HEAVY WALL XM804, J8152-3

1. SAE 1064 or 1044 steel.
2. No heat treat.
3. Cavity standard's loose.
4. Interior phosphatized but not painted.
5. No base cover.
6. Ballistic lot sample: 20 rounds/20,000 each ($0.045/round less if samples not required).
7. Government-furnished grommets and lifting plugs.
8. Government-furnished utilities ($4/round additional if utilities are required).
9. Non-recurring cost:

	$53,000	Tooling	(Not included in prices)
	27,000	Setup and Start	
	$80,000	Total	

Note: $0.08/round/1,000,000 rounds.

10. FOB Scranton.
11. Concurrent production with M107 (50,000/month).
12. Price: $51.67 each at 17,000 each/month (204,000/year).
$46.59 each at 20,000 to 22,000 each/month (Most Economical Rate) (264,000/year)

Note: Training rounds to be produced on second shift only.

PRICE. FOR 1,000,000 RDS

51.67 + $0.08 TOOLING & START-UP = 51.75/EA @ 17K/MONTH

46.59 + $0.08 TOOLING & START-UP = 46.67/EA @ 22K/MONTH

26 June 1978

CHAMBERLAIN NEW BEDFORD DIVISION PRODUCTION COST ESTIMATE

HEAVY WALL XM804, J8152-3

Cost Per Round:

1.	Body Fabrication	$24.80	(1046 steel)
2.	Rotating Band	1.93	
3.	Pallet	1.35	
4.	Labor	2.00	
5.	Burden	4.04	
6.	Tooling	* 2.25	(First 200,000 rounds only)
7.	Startup	* 5.67	(First 200,000 rounds only)
8.	G&A	3.36	
9.	Profit	4.54	
10.	Total Cost	$49.94	(at 25,000 each/month)

11. FOB New Bedford

12. Utilities included in price.

13. Government-furnished grommets and lifting plug.

14. Concurrent production with M483 round (30,000 each/month).

$$* \text{ TOOLING } \& \text{ START-UP} = \frac{(2.25 + 5.67)(200,000)}{1,000,000} = \$1.584 \text{ EA / MILLION RDS}$$

$$\$49.94 - (2.25 + 5.67) + 1.584 = \$43.60 \text{ EA / MILLION RDS}$$

NO. 160

LynchburgFoundry
a Mead Company

CASTINGS SALES OFFICES
DETROIT
NEW YORK

DRAWER 411
LYNCHBURG, VIRGINIA 24505
804/847-1900

PLANTS
LYNCHBURG, VIRGINIA
ARCHER CREEK, VIRGINIA
RADFORD, VIRGINIA

April 14, 1977

In reply please refer to our quotation

No. AC-53-77-L

Chamberlain Mfg. Corp.
Research & Development Div.
East 4th & Ester Sts.
Waterloo, Iowa 50705

Attention: Mr. Dennis D. Kaisand

Gentlemen: In reply to your inquiry recently we are pleased to submit the following prices:

Drawing No.	Description	Weight	Minimum Lot Size	Price
M107 Per Sketch	Practice Round (400M/Yr. 8M/Wk)	100#		$36.00 ea.

Require two (2) cast iron patterns mounted, gated, and rigged on 24" x 32" cast iron plates with the following core equipment:
1 - 4-gang cast iron isocure core box.

Price based on making with a 2Ø cored hole on the blind end.

Comment: We will commit to a maximum of 5,000 tons per year at this time, until we have produced this casting and evaluated our actual experiences. Any tonnage commitment over this would be at our option, at time of consideration.

Require 1/8" finish plus draft. ± 1/16" general casting tolerances.

Terms: See Reverse Side Projected Delivery Samples in approximately 6 weeks after receipt of purchase order & drawings (experimental pattern).

F.O.B. Shipping Point Price Covers: Unmachined Castings (unless otherwise specified)

Please note the Terms and Conditions on the reverse side, and any addendum pages attached, which are a part of this quotation.

continued.......

Very truly yours,

LYNCHBURG FOUNDRY

C. L. Perkins

C. L. Perkins

Chamberlain Mfg. Corp.
Waterloo, Iowa 50705

Quotation No. AC-53-77-L
April 14, 1977

Iron Specs: Ductile Iron 60-40-18 with 143-187 BHN. Heat treat included.

We have not secured pattern prices at this time, however, we will be glad to secure same in the event you are interested in placing orders with us.

Our quoted prices are based on a steel scrap base of $85.00 per ton with a plus or minus $10.00 per ton adjustment factor before any surcharging would be implemented. The actual surcharging will be only that part that is above or below the ± $10.00.

LYNCHBURG FOUNDRY

*COST ANALYSIS FOR INERT-LOADING OF STANDARD 155-MM, M107 PROJECTILE (HYDRO-CAL)

EQUIPMENT

Estimated cost for inert-loading machinery is $82,000.00 with machinery to be completely depreciated in five (5) years.

MATERIAL (INERT COMPOSITION)

14.6 + 10% losses = 16.06lbs. @ .06215/lb. = $.998

DIRECT MANUFACTURING LABOR

1. Transfer painted shell from production conveyor to loading machine, remove lifting eye.
2. Operator to monitor all loading cycles.
3. Lubricate thread, add lifting eye and transfer shell to production conveyor.
4. Inert composition mixer.
5. Material handler-relief man.
6. Quality-Inspector.

Six unskilled operators will be required to load 125 shells per hour.

6 operators @ $7.00/Hr. = 42.00 125 shells.	.34
Manufacturing overhead @ 200%	.68
Material-Composition	1.00
	2.02
General administrative costs @ 5%	.10
	2.12
Profit @ 12%	.25
Total cost	$2.37

COSTS COMPARISON-CURRENT vs. PROPOSED SYSTEM

Current inert-loading	200,000 Shells @ $24.00	$4,800,000.00
Proposed inert-loading	200,000 Shells @ 2.37	474,000.00
Savings		$4,326,000.00

Collateral savings resulting by eliminating double handling with damage and added transportation not included in this analysis.

*As provided to Chamberlain by ARRADCOM

FINAL TECHNICAL REPORT DISTRIBUTION

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SUPPLEMENTAR

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Chamberlain Manufacturing Corporation
RESEARCH & DEVELOPMENT DIV. WATERLOO, IOWA

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ENGINEERING CHANGE NUMBER: N/A

DWG/DOC TITLE: DESIGN, DEVELOPMENT AND FABRICATION OF TRAINING ROUND TO SIMULATE PROJECTILE, 155-MM, HE, M107 (XM804)

ADDITIONAL APPROVALS REQUIRED: None

		DATE
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PROJECT APPVL	E. Steiner Edwin Steiner	19 Mar 80

RELEASE DATE: 19 March 1980

DESCRIPTION OF CHANGE, REASON FOR CHANGE, SPECIAL HANDLING INSTRUCTIONS, ETC.:

Remove Pages 1 through 4 from the Final Technical Report described above and substitute the revised pages attached hereto (Contract DAAK10-78-C-0072).

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1. INTRODUCTION AND BACKGROUND

1.1 On 9 February 1978 Chamberlain was awarded the subject contract to design and develop a 155-mm Training Projectile, XM804, which would be 40% to 50% more economical to manufacture than the 155-mm, M107 HE Projectile and still meet the following requirements:

- Have the same exterior configuration as the M107 Projectile.
- Match the M107 Projectile ballistically.
- Withstand the Charge, Zone 5 gun firing environment.

1.2 An estimated quantity of more than 200,000 each inert M107 Projectiles per year is needed to train and maintain the proficiency of field artillery crews. The expense of using the standard HE M107 round for this purpose might restrict adequate training. The development of an inexpensive inert facsimile of the M107 round which had ballistic similitude would assure the maintenance of fully trained artillery crews.

1.3 This initial phase of the program included estimates of initial casting facility costs and rationale plus full scale forged and cast unit production cost and rationale based on quantities of 200,000 units per year for five years.

2. CONCLUSIONS

2.1 The objectives of the subject contract were met or exceeded by the accomplishment of the following work:

- A design was developed for the forged 155-mm, XM804 "Heavy-Wall," Empty, Projectile. NOTE: The "heavy wall" design simulates the HE loaded projectile by utilizing a heavier steel wall to replace the HE.
- Because post-heat treatment is not required to obtain the required physicals, the XM804 heavy-wall projectile can be fabricated from AISI C1340 steel at lower cost than from the originally specified AISI C1046 steel.
- Dynamic firing of 155-mm, XM804 Projectiles and standard 155-mm, M107 Projectiles showed that the XM804 round had the required ballistic similitude.
- Metal Parts Security Tests showed that the XM804 Projectile would withstand the environment imposed by firing at Charge, Zone 7. (Charge, Zone 5 would be the normal maximum charge for training purposes.)
- Production cost estimates showed that the forged training round represents a 41% savings in manufacturing costs.
- The results of dynamic firings indicated that the inert "Hydro-Cal" load may be a substitute for the inert wax load in the standard 155-mm, M107 Projectile.
- A method for manufacturing the XM804 Projectile by pressure casting was demonstrated and appears feasible; however, extensive development of the process would be required for finalization of the manufacturing techniques involved.

3. RECOMMENDATIONS

3.1 The following recommendations were based on the results of work accomplished during the performance of the subject contract.

- It is recommended that the forged 155-mm, XM804 "heavy-wall" projectile be type classified and placed in the inventory as soon as possible.
- It is recommended that the three cast XM804's now at Yuma Proving Ground be gun fired as soon as possible to verify their structural integrity.
- Dynamic firings at Charge, Zone 7 should be conducted on the "Hydro-Cal" loaded M107 Projectile to prove the suitability of this load.

4. DESIGN APPROACHES

4.1 The program was initiated with cost studies for the purpose of selecting one forged projectile concept and one cast projectile concept which were to be developed upon Government approval. The following types of body designs were investigated:

- A forged body with "heavy" walls
- An inert-filled M107 shell (forged type)
- A pressure-cast shell
- A sand-cast shell.

Of these four approaches, the sand casting approach was eliminated early in the program based on preliminary studies which indicated that it would not be cost effective. The estimated cost of the rough casting, itself, was considerably higher than the estimated cost of the forging. The sand cast version of the projectile could be completed only as a two-piece assembly which would have generated additional costs and potential production problems.

4.2 The standard M107 Projectiles currently are made from AISI C1046 heat treated steel; however, AISI C1064 heat treated steel is specified as an alternate material and is available at lower cost. Therefore, the cheaper alternate 1064 steel was considered in the XM804 cost estimates. Because a porosity seal was not required for inert rounds, the Base Cover (Ordnance Drawing No. 10535928) was omitted from the XM804 and inspection of the inside cavity for pits and subsequent reclaim operations were eliminated. In addition, the loading nose plug (lifting eye) was omitted and the nose threads were to be protected by a thin plastic plug cover.

4.3 The following design parameters were established for both the cast and the forged XM804 Projectile:

- Weight: 94.7 lbs. ± 1.3 lbs. (Weight Zones 4 and 5)
- Center of Gravity: 9.36 inches from base
- Moments of Inertia: Polar - 499.2 lbs.-in.^{2}
  Transverse - 4,311 lbs.-in.^{2}

The nose fuze was included in all of the above calculations.